Canada. Geodetic Service

DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL J. OGILVIE, Director

ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDED MARCH 31, 1926

1925/26

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1927

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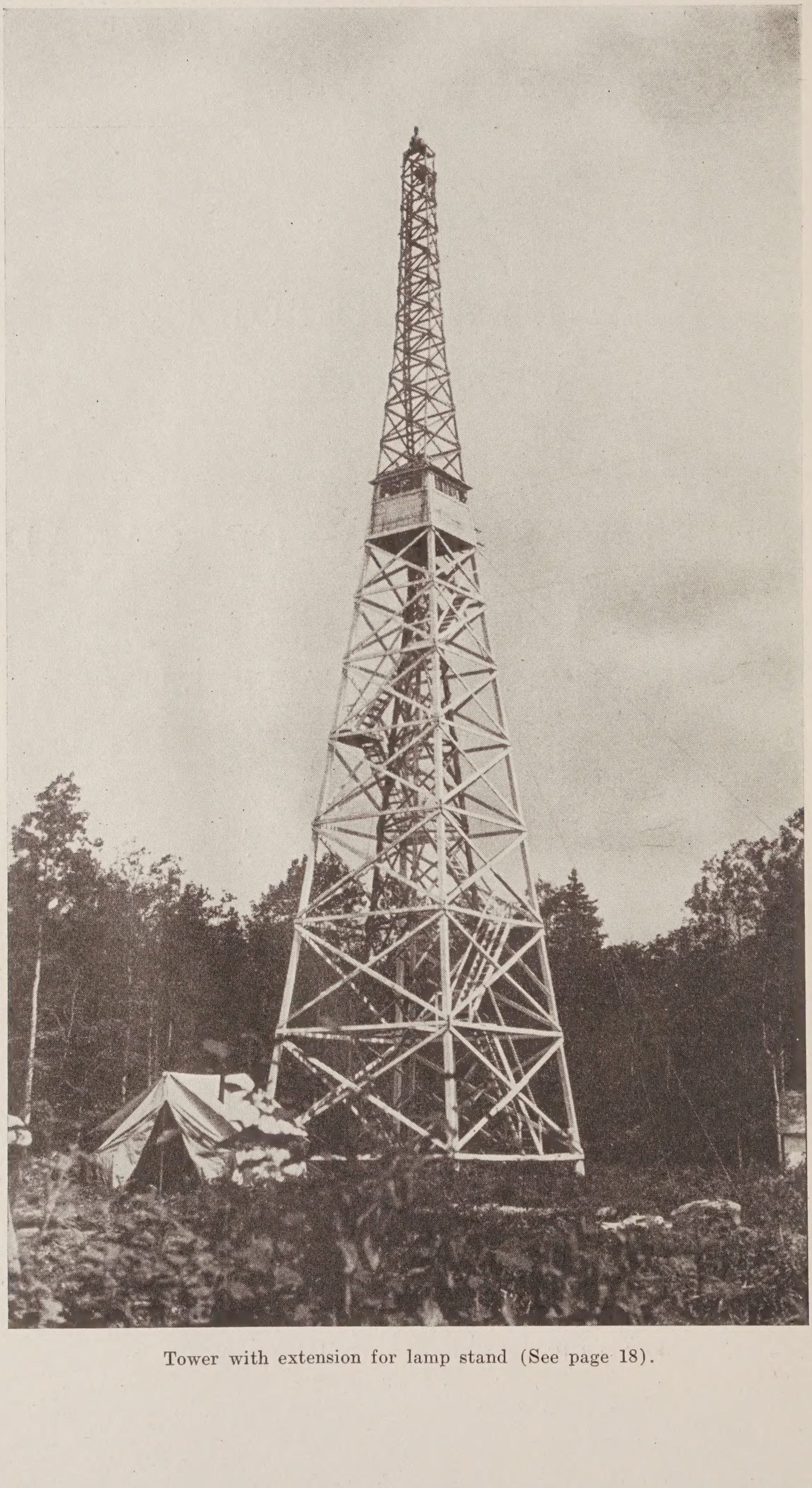

Tower with extension for lamp stand (See page 18).

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GEODETIC SURVEY OF CANADA

REPORT OF THE DIRECTOR, NOEL J. OGILVIE

Satisfactory progress has characterized both field and office operations of the Geodetic Survey during the fiscal year ended March 31, 1926. Field work was carried on in all nine provinces.

CENTRAL BUREAU OF GEOGRAPHIC POSITIONS AND ELEVATIONS

A policy of co-ordination and centralization of geographic and levelling data has recently been carried on under the department policy of co-operation between federal and provincial authorities, public service organizations, and private companies, and should render a distinct public service and fill a long felt need in Canada.

For many years such a policy has been periodically recommended by various committees. Valuable information secured at considerable cost has been gathered by many organizations for particular purposes, but as no central agency for co-ordinating and issuing this data existed the results remained to a large extent scattered through the several offices in which they originated; they were seldom published, their existence was frequently unknown to the public, and their use was therefore much restricted.

An exception to the above condition is the valuable official publication of successive editions of " Altitudes in Canada." The continuation and extension of this work has been entrusted to this survey.

A difficulty in centralization and co-ordination in the early days was the absence of any framework by which co-ordination could be effected, but this difficulty is now being overcome with the extension of the triangulation and precise level nets over Canada. As fast as possible the policy will be extended so that any one requiring geographic positions or elevations in the Dominion will be able to obtain all available data from the Geodetic Survey of Canada. What this service means may be appreciated when one considers the very numerous sources from which this information is derived, and the difficulty, and even impossibility, of obtaining full and co-ordinated information in any other manner. This information will be published with appropriate acknowledgments from time to time as opportunity occurs.

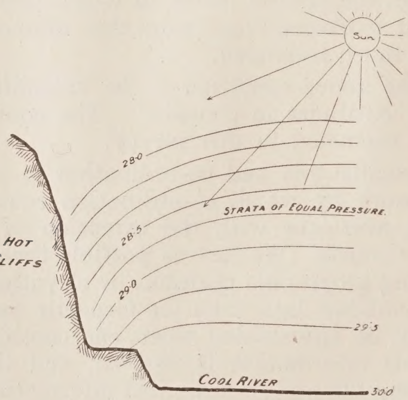
LATERAL REFRACTION

In the Annual Report of the Director of the Geodetic Survey of Canada for the fiscal year ended March 31, 1925, a number of examples of lateral, or horizontal, refraction were given and the probable causes suggested. The season of 1925 provided further examples of the occurrence of this phenomenon and permitted the underlying causes in certain cases to be still further investigated. The conclusion may be drawn that consistent horizontal refraction is simply a variation of vertical refraction, and is due to the same causes.

In the Lower St. Lawrence River net it was shown that in a large majority of cases the lines parallel to the river were "bent" *towards the river.* The explanation suggested was that the air strata followed somewhat the topography and dipped towards the river, thus causing the plane through the curved path of the ray of light (which is perpendicular to the plane of the air strata) to be inclined towards the river and therefore causing the light to appear to emanate from a point on the river side of, and above, its true position, rather than vertically above. No explanation of why the air strata should be thus tilted was hazarded.

During the month of July, 1925, in the course of the measurement of a precise traverse on the railway tracks along the Skeena river in British Columbia aggravated cases of horizontal refraction occurred. In this case the lines were "bent" *away from the river* and towards the hills, just the opposite of the effect in the St. Lawrence river area noted above.

The railway runs in a general east and west direction along the north bank of the river at the base of cliffs many hundreds of feet high. The sun therefore shone on these cliffs during most of the day. Due to the great number of curves in the railway line the traverse courses were short, varying from 100 to 2,000 meters in length. Measurements of traverse angles made in strong sunlight showed consistently that the traverse courses were "bent" *towards the cliffs,* the angular error increasing with the length of the course. Reobservation of the angles at sixty-five traverse stations at night or on dull days disclosed errors of from three to five seconds for 100 to 200 meter lines and as high as twenty seconds for lines a mile in length. In all cases the sign of the angular errors showed that when the observations were made in bright sunlight the lines were "bent" towards the cliffs.

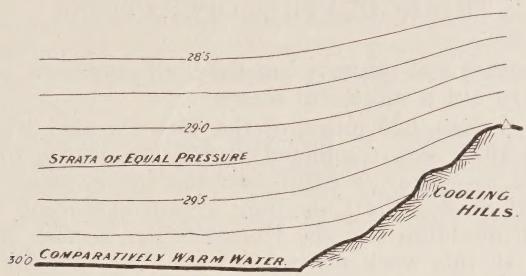


Probable condition of air strata on hot day on Skeena river, British Columbia.

The explanation advanced is that the air close to the cliffs became heated, greatly expanded, and was therefore much less dense than the air at equal elevations further away from the cliffs. The layers of air of equal density or pressure therefore dipped towards the cliffs somewhat after the fashion shown on the accompanying sketch, and the plane of the refracted ray of light passing through these layers of different density may have been tilted considerably from a vertical plane and possibly in extreme cases even to a horizontal plane.

This theory may be used to further explain the St. Lawrence River horizontal refraction. The observations in this area were made on lights after sundown,

when the land surface was cooling rapidly. This cooling would produce a contraction of the air with consequent greater density over the land surface, and as the land became cooler than the water the strata of air of equal density would dip towards the water and produce the "bending" so consistently noted.



Probable condition of air strata on cool night on lower St. Lawrence river, Quebec.

According to this theory it might be anticipated that no horizontal refraction would have been noted had the observations been taken in the daytime in cloudy weather, and that had they been taken in bright sunlight the results might have been reversed and the lines appear "bent" towards the land as in the traverse in British Columbia above referred to.

MOUNT LOGAN EXPEDITION

Canada's greatest altitude is reached at the summit of Mount Logan, 19,850 feet, and situated at the extreme southwest of the Yukon.

This summit was climbed for the first time June 23, 1925. Of the six men who completed the climb, three were Canadians: H. F. Lambart, of the Geodetic Survey of Canada; Col. W. W. Foster, of Vancouver, B.C.; and Andrew Taylor, of Ottawa.

The annual report of the Geodetic Survey for the year 1925-26 would not be complete without reference to the Mount Logan Expedition. The release of Mr. Lambart of the Geodetic Survey of Canada to become deputy leader of the expedition signified the co-operation of the Government in this the greatest Alpine enterprise in the history of Canada. The story of the expedition is not recounted here. Accounts have appeared in the Royal Geographical Journal, the National Geographic Magazine, and other publications, and many supplementary details have been filed with the Geodetic Survey. These are the first records of a first-hand knowledge of an expanse of territory hitherto unseen within whose limits lie some of the greatest mountains and glaciers on the continent.

The aneroid barometer which was carried to the summit of Mount Logan was specially made to meet specifications drawn up by the Physical Testing Laboratory of the Department of the Interior. The instrument embodied the latest improvements in aneroid design, and had very small thermal and elastic errors, being one of the most accurate aneroids ever carried on a mountaineering expedition.

The Reports on clothing, sleeping outfits, stoves, fuel, tents, provisions, etc., will be of permanent value as a reference for future expeditions. These matters were under the personal direction of Mr. Lambart.

An invaluable collection of negatives has been added to the photographic records of the department and, in addition to these still photographs, 2,500 feet of moving picture film of the ascent beyond the last growth of timber was secured. Thus the climb in all its various stages is chronicled for all time.

The special interest of the Department of the Interior on the Mount Logan Expedition was the confirmation of the methods of photographic surveying developed and perfected in the department.

TRIANGULATION OPERATIONS

Favourable weather and improved methods of operation permitted the field parties to again carry out a successful season.

The Canadian section, 625 miles, of the 49th Parallel triangulation, which was commenced in 1921, was completed during the season of 1925. This net was the result of a co-operative effort between the geodetic services of Canada and the United States, the Canadian section extending from lake of the Woods to the 109th meridian and the United States section from that point to the Pacific coast. In this work all stations on the Canadian side of the line, whether established by Canadian or United States parties were marked by bronze tablets bearing Canadian inscriptions. Similarly all stations on the United States side were marked by tablets bearing United States inscriptions. The number of direction measurements made on the Canadian section during 1925 constituted a record for the Geodetic Survey.

During the fiscal year Geodetic Survey officials have tested a new type of transit on triangulation work. This type has incorporated in it a number of radical departures from generally accepted designs, and quite upsets past conceptions as to the relation between size and weight and attainable accuracy. The main differences in the new type are the very large reduction in weight and increased speed of operation, without loss of accuracy, over older types—two features which have been greatly sought after in geodetic theodolites in Canada to counteract the difficulties of transportation and the high cost of labour.

Various stages of triangulation or precise traverse operations were carried on in all provinces except Saskatchewan, a résumé of the progress being as follows:—

Nova Scotia.—Work in this province was confined to a reconnaissance for the selection of stations along the coast southwest from Halifax to cape Sable, and to the start of a net connecting the north and south shores near Digby and Liverpool respectively.

Prince Edward Island.—A number of stations were selected which practically serve the island with primary triangulation, previously selected stations having been confined to the south and east coasts. Two stations at the southwest end were occupied for direction measurements in connection with the New Brunswick triangulation.

New Brunswick.—Splendid progress was made in the observing of the New Brunswick coast net. The connection was completed at the mouth of Chaleur bay with the St. Lawrence net; thence the parties worked south and exceeded anticipation of their progress by almost finishing the eastern New Brunswick coast net. This will be completed in 1926 as will also the observing in Prince Edward Island. The positions of most of the important church spires and lighthouses along the coast have been determined.

Quebec.—The work in the Chaleur bay area, already referred to, was completed, and the reconnaissance for continuing the triangulation along the north shore of the gulf of St. Lawrence was advanced as far as St. Augustine.

As predicted in the 1925 report the Saguenay-Lake St. John-Three Rivers loop was completed during the season. From Linton south this net was observed with primary accuracy, as it is intended to extend it in 1926 northwest towards La Tuque and along the transcontinental railway (C.N.R.).

Ontario and Quebec.—The Ottawa River net was extended during the season of 1925. Angular measurements were completed to Kipawa, P.Q., and stations selected as far as Englehart, Ont. Transport was confined to one road along the Ottawa river as far as Mattawa, with back-packing along bush roads back from the main road, while above Mattawa canoe transport was necessary.

Manitoba.—The work accomplished here during the season forms a record, as angular measurements were completed along the 49th Parallel net from the west boundary of Manitoba as far east as Emerson, together with those on a spur net north to Brandon.

Alberta.—Reconnaissance for selection of stations had been commenced in 1920 at the International Boundary south of Medicine Hat and carried north and west towards Calgary. This net was continued north to Calgary and Edmonton. From this net branches to the west from these two points will be carried on in 1926.

British Columbia.—From Prince Rupert east along the Canadian National railway precise traverse was carried during 1925 for about 120 miles to Pacific, B.C. Precise traverse was substituted for primary triangulation in this section only because of the tremendous difficulties and expense of transportation in country of this type.

This traverse will be continued in 1926 to the eastern side of the Bulkley range, from which point primary triangulation will again be carried eastward across the province and southward towards Vancouver.

Precise Traverse in Northern British Columbia

Results Obtained.—One hundred and nineteen miles of traverse completed; 29 permanently marked stations established; 493 unmarked stations occupied.

During the season of 1925 the Skeena River section of the control net for the interior of northern British Columbia was surveyed. The course of this net is eastward from Prince Rupert, across the province, then southward and westward to Vancouver, where it again connects with the primary triangulation of the coast.

As the valley of the Skeena is narrow any triangulation figures straddling it would be elongated in the direction of progress, and it is probable that their accuracy would not have been greater than that of a precise traverse. In addition, the difficulties of transportation would have rendered the cost of triangulation excessive, and it was therefore decided to run precise traverse through this area, even though the country was ill-suited to this method on account of the large number of curves in the railway track. Another point in favour of the precise traverse was that it established the stations along the railway and, consequently near the settlements, where they are most useful, while the geographic positions of nearby mountain tops can easily be determined.

The field operations were carried out in accordance with established practice. The lengths of the traverse courses depend on one measurement made in one direction with 50-metre invar tape, supported on the rail along tangents, and on posts or tripods at 25-metre intervals, on curves. Three invar tapes were used. One was kept in camp for a standard and two were used for measuring, alternating with each other every fifteen kilometers. A check measurement was made with a 300-foot steel tape to detect possible gross errors. The elevations of the ends of each tape length were taken to compute the correction for slope.

An azimuth line was carried along with the traverse line to maintain the direction. The minimum length of the courses in this line was about one mile and each course was connected, at one or both ends, to the chainage of the traverse line. Together the two lines thus formed a series of closed loops which provided a check on the angular measurements as the work progressed. All

angles were measured with a 12-inch Kern theodolite, using the direction method. Angular measurements could be made in daylight only in cloudy weather, and when the sun was shining and refraction consequently bad, they were delayed until the late afternoon and night (see page 6 for details of horizontal refraction).

The party used three track motors for transportation and was made up of nineteen men all told, including three trainmen, one for each motor.

The season comprised only ninety-one actual working days.

Primary Triangulation along the 49th Parallel

Results Obtained.—Reconnaissance—54 stations selected; distance covered, 365 miles. Station preparation—60 stations marked with piers; distance covered, 450 miles. Angular measurements—49 stations completed; distance covered, 235 miles.

Operations were carried on by three parties covering, respectively, reconnaissance, station marking and direction measurement. The personnel of these parties was almost the same as that of the past two years. To this fact is attributed the exceptional speed with which the work was pushed forward. Without doubt, careful selection and training of personnel is one of the most important factors in increasing the efficiency of any survey party.

In general, the weather conditions during the season of 1925 were unfavourable. The greatest loss of time due to this cause occurred while the angle measurement party was working across the Turtle mountains, although even here the loss was caused more by added difficulties of transportation than by inability to make measurements in bad weather. Any extended period of rain makes the second-class road almost impassable, and on one occasion, the angle measurement party required eighteen working hours to move its outfit thirty-two miles into the district south of Boissevain, Man.

Reconnaissance.—This work was begun in the vicinity of Brooks, Alta., and a connection was made here with the preliminary work carried north from the International Boundary in 1920. The original work, begun at United States Coast and Geodetic stations in the Sweet Grass hills, had been carried north and west as far as Gleichen, Alta., but it was thought that the lines from Brooks westward were too long and would cause difficulty in the neighbourhood of Calgary if carried forward on the same scale, while a revision of the last two figures, reducing the lengths of lines, would save time later.

Progress on this work was very satisfactory. The scheme laid down during the summer extends westerly toward Calgary, thence northerly to Edmonton. This chain will extend westward into the mountains from Edmonton to meet the triangulation net of northern British Columbia. This connection, when made, will not only support the northern end of this Alberta net, but will supply rigidity to the British Columbia coast and interior nets.

Connections were made in the vicinity of Calgary with the secondary triangulation of the Railway Belt of British Columbia carried out by the Topographical Survey and also with the Rocky Mountain secondary net of the Geological Survey. The rigidity of these two important chains of secondary triangulation will be greatly increased when these connections with the primary triangulation are completed.

Serious consideration was given in all cases to the fact that satisfactory control should be left available in the neighbourhood of the main centres of population along the chain of triangulation.

Station Preparation.—This operation consisted of placing the concrete piers for permanent marking of primary stations. As no towers were to be built during the season, the party was organized on a smaller scale than for the previous year.

Experience has shown that a party, properly organized, trained and equipped, carrying out a single type of work, can achieve a much lower unit cost than when carrying on a number of operations of a diversified nature. To take advantage of this fact, the reconnaissance should be far enough in advance of preparation of stations to justify the organization of a party which is essentially a tower building unit one year, and a pier building party the following year, or two years, alternating as required. In this way the work in this type of country, where transportation is easy and cheap, can be done at a lower cost, per unit, than when tower work and pier building are being carried on together by a single party. Other economies can be achieved by the use of modern equipment if the work can be planned far enough in advance to justify expenditure on such equipment.

The station preparation party followed the reconnaissance work previously done and placed standard piers at all stations on the 49th Parallel between Emerson and Pilot Mound, Man. This party then moved to Killarney and placed piers at all stations in the net running north to Camp Hughes, Man., and on the completion of this section they were moved farther west and completed marking of stations from the International Boundary, as far north as Olds, Alta., where the party was disbanded.

Angle Measurement.—It was expected that the United States Coast and Geodetic Survey would finish their section of the 49th Parallel triangulation during 1925, so that although there were still forty-one stations on the Canadian section to be occupied and only one party available, an effort was made from the beginning to complete this work during the season. Despite adverse weather this party completed the field work required and occupied eight additional stations on the net from Killarney to Camp Hughes.

The experience of the season of 1925 seems to justify the opinion formed in the three preceding years that a generous allowance must be made on the prairie work for loss of time due to the necessity of offsetting the effects of lateral refraction.

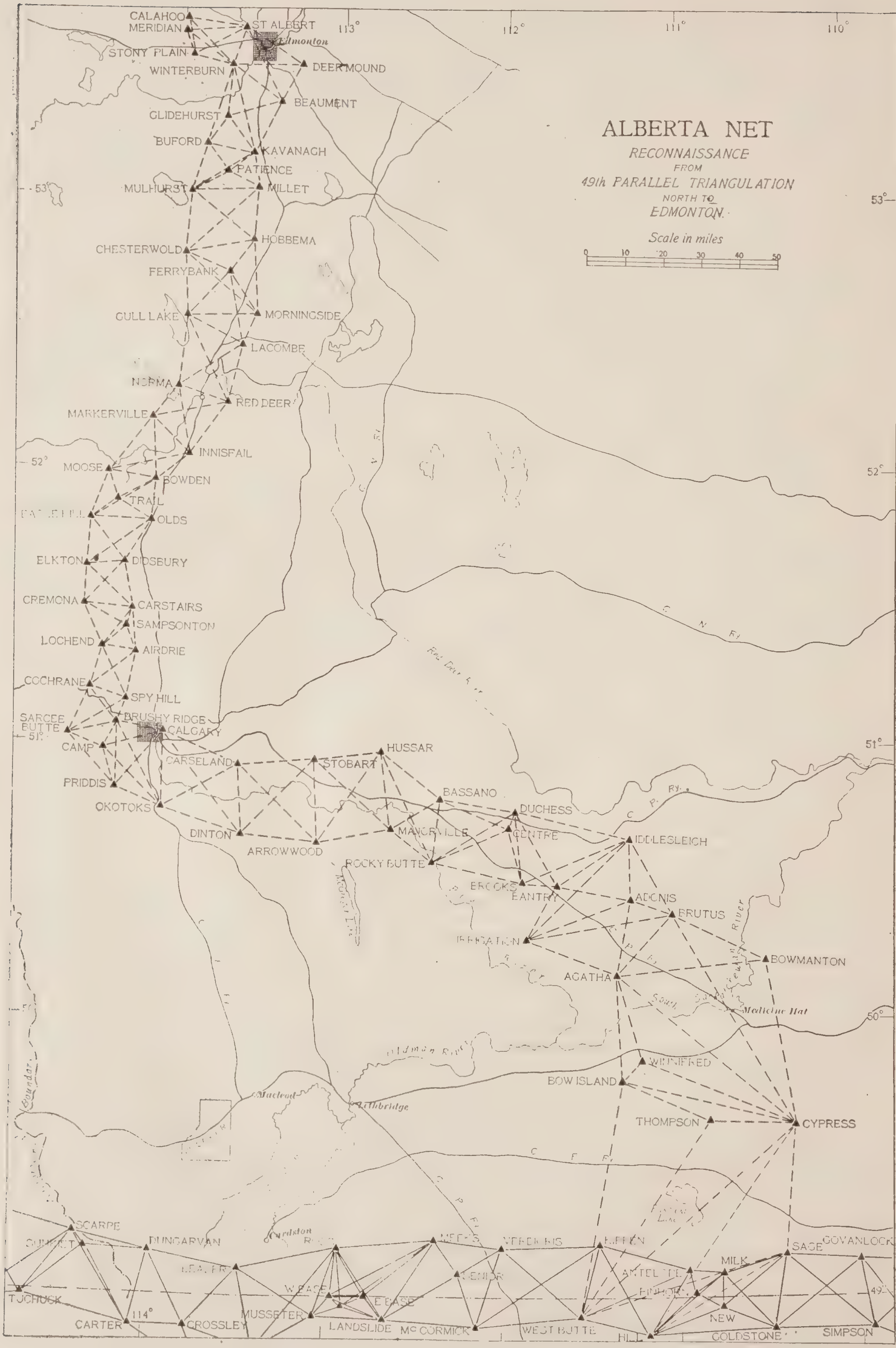
A sketch of the triangulation reconnaissance in Alberta is shown on page 12.

Upper Ottawa River Primary Triangulation

Results Obtained.—Reconnaissance—26 primary stations and 1 supplementary station selected; 1 base line selected and examined; distance covered, 144 miles. Station preparation—18 stations marked with monuments; towers built at 9 stations; distance covered, 110 miles. Angular measurements—11 primary and 3 supplementary stations completed; distance covered, 90 miles.

This work was a continuation of that of the previous season, operations being carried forward by three parties covering respectively reconnaissance, station preparation and tower building, and direction measurement.

The reconnaissance party started work at Mattawa, Ont., and carried the work up the Ottawa river and Kipawa lake to a point about half way up lake Timiskaming where a junction was made to a base net selected earlier in the season. The party then moved to the northerly end of the base net near Earlton, Ont., and worked as far as Swastika, Ont., near the height of land. The district from Mattawa to the northerly end of Kipawa lake presented many difficulties in the selection of stations as the hill tops, although high, were heavily timbered with hardwood and in the majority of cases were about the same height over a large section. Northward from Cobalt open country with numerous roads was entered, so that motor transport could be again used. Here also the hills were more prominent and in consequence the reconnaissance was much easier. Progress here was quite rapid with very strong figures.


ALBERTA NET
RECONNAISSANCE
FROM
49th PARALLEL TRIANGULATION
NORTH TO
EDMONTON
Scale in miles
0 10 20 30 40 50
113°
112°
111°
110°
53°
52°
51°
50°
49°
114°
CALAHOO
MERIDIAN
ST ALBERT
Edmonton
STONY PLAIN
WINTERBURN
DEERMOUND
BEAUMENT
GLIDEHURST
BUFORD
KAVANAGH
PATIENCE
MULHURST
MILLET
HOBBEMA
CHESTERWOLD
FERRYBANK
GULL LAKE
MORNINGSIDE
LACOMBE
NORMA
RED DEER
MARKERVILLE
INNISFAIL
MOOSE
BOWDEN
TRAIL
OLDS
ELKTON
DIDSBURY
CREMONA
CARSTAIRS
SAMPSONTON
LOCHEND
AIRDRIE
COCHRANE
SPY HILL
SARCEE BUTTE
BRUSHY RIDGE
CALGARY
CAMP
CARSELAND
STOBART
HUSSAR
PRIDDIS
OKOTOKS
BASSANO
DUCHESS
DINTON
ARROWWOOD
CENTRE
IDDLESLEIGH
ROCKY BUTTE
BROOKS
EANTRY
ADONIS
BRUTUS
BOWMANTON
AGATHA
Medicine Hat
WINIFRED
BOW ISLAND
THOMPSON
CYPRESS
Macleod
Lethbridge
SCARPE
DUNGARVAN
SAGE
GOVANLOCK
MILK
NEW
TUCHUCK
CARTER
CROSSLEY
MUSSETER
W BASE
E BASE
LANDSLIDE
McCORMICK
WEST BUTTE
HILL
COLDSTONE
SIMPSON

North of Englehart the country is wooded, with flat hills and, as in this section there are very few roads, the travelling was again difficult. This difficult section is short, and it will be fairly easy to carry the reconnaissance to Cochrane, Ont.

The station preparation party also started work at Mattawa, Ont., and worked to the north end of lake Timiskaming.

The direction measurement party started work forty miles above Pembroke, Ont., and completed the scheme as far as Kipawa, P.Q., putting in three supplementary stations as the work progressed. The preliminary tests show all the direction measurements to be very good. Two of the stations were connected by levels with precise level bench-marks to give control for a system of approximate heights by trigonometric levelling.

Progress was considerably retarded during the season owing to the lack of motor roads to many of the stations. The slower and more primitive methods of back-packing and, in some cases, canoe transport had to be resorted to.

A sketch of the Upper Ottawa River triangulation appears on page 14.

Primary Triangulation in Northern Quebec

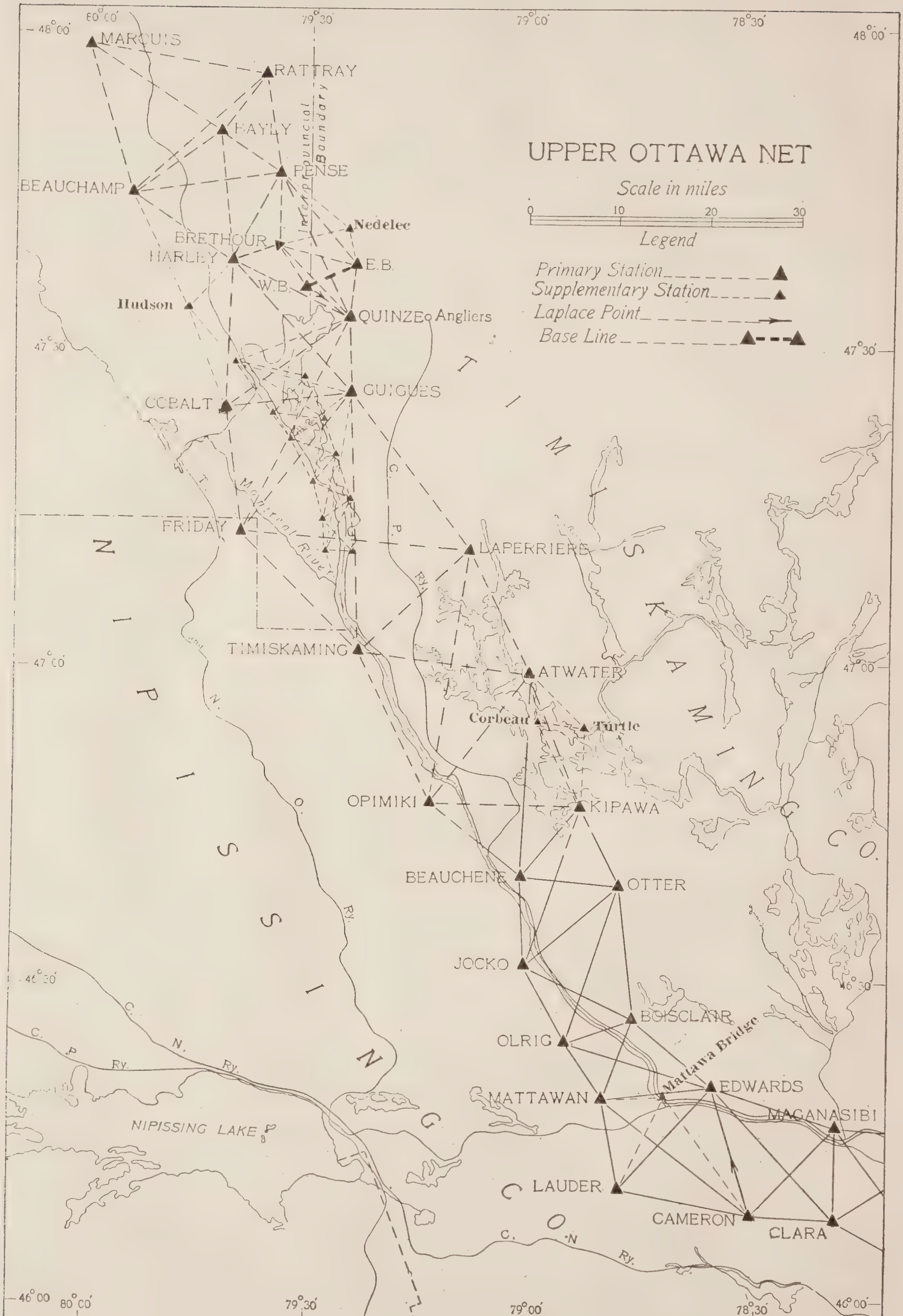
Results Obtained.—Reconnaissance—14 primary station sites selected; 2 Laplace stations selected; 1 base line selected (see page... for description of measurement); distance covered, 65 miles. Stations preparation—14 stations permanently marked; distance covered, 65 miles. Angular measurement—20 stations completed; including 6 which were previously secondary stations; positions of 8 church spires determined; distance covered, 65 miles.

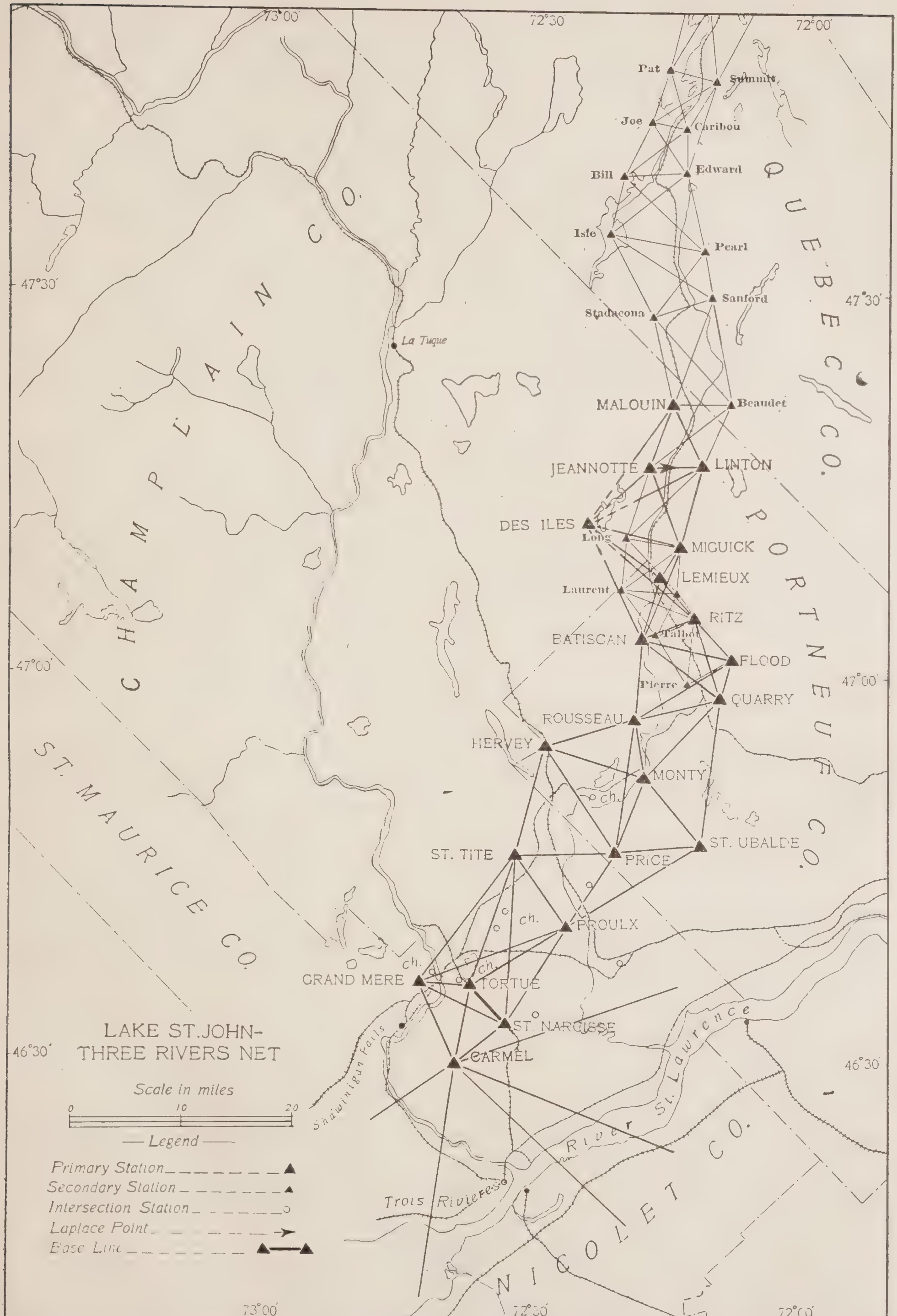
The season of 1925 was spent on the closing link of the Saguenay River-Lake St. John-Three Rivers chain of triangulation which was commenced in 1921 at the mouth of the Saguenay river near Tadoussac. Previous to this year this net was extended by primary or secondary triangulation to lake St. John, thence southerly along the Quebec and Lake St. John branch of the Canadian National railway. By the end of the 1924 season the net had reached Rivière-à-Pierre. The 1925 work consisted of revising the last twenty-five miles of the secondary net from Linton to Rivière-à-Pierre to secure primary accuracy and of continuing this primary net southwesterly forty miles from Rivière-à-Pierre to near Three Rivers, to connect with the main St. Lawrence River net. The link from Linton to Three Rivers was carried out with primary accuracy since from near Linton it was to be extended westerly to La Tuque and along the transcontinental line of the Canadian National Railway system as a primary net. In the revision of the twenty-five miles of secondary triangulation two new stations were selected and two eliminated. The net then continued along the Canadian National railway line to Carmel station, one of the stations in the St. Lawrence River triangulation system.

The connection to the main St. Lawrence net was unusual. Generally, connection is made to two stations, thus providing a check in latitude, longitude, azimuth and distance. As the stations of the St. Lawrence net were far apart this method was not economical and a check on the latitude and longitude was secured by connection to a single station, Carmel. An azimuth check was secured by observing over the line Carmel-Dusable of the St. Lawrence net and a check on the distance between stations was obtained by selecting a base line along a railway tangent near lac a la Tortue. (See page 23 for description of the measurement of this line.)

Towers were required at a majority of the stations to overcome obstruction due to local timber. The heights ranged from twenty to seventy feet, with an average of thirty-six feet.

A sketch of this net is shown on page 15.


UPPER OTTAWA NET
Scale in miles
0 10 20 30
Legend
Primary Station
Supplementary Station
Laplace Point
Base Line
MARQUIS
RATTRAY
BAYLY
PENSE
BEAUCHAMP
Nedelec
BRETHOUR
HARLEY
E.B.
W.B.
Hudson
QUINZE
Angliers
GUIGUES
COBALT
FRIDAY
LAPERRIERE
TIMISKAMING
ATWATER
Corbeau
Turtle
OPIMIKI
KIPAWA
BEAUCHENE
OTTER
JOCKO
BOISCLAIR
OLRIG
Mattawa Bridge
EDWARDS
MATTAWAN
MAGANASIBI
LAUDER
CAMERON
CLARA
NIPISSING LAKE
Interprovincial Boundary
Montreal River
T. & N. O. Ry.
C. P. Ry.
C. N. Ry.
NIPISSING
TIMISKAMING CO.
48°00′
47°30′
47°00′
46°30′
46°00′
80°00′
79°30′
79°00′
78°30′


LAKE ST. JOHN-
THREE RIVERS NET
Scale in miles
0 10 20
— Legend —
Primary Station
Secondary Station
Intersection Station
Laplace Point
Base Line
73°00′
72°30′
72°00′
47°30′
47°00′
46°30′
CHAMPLAIN CO.
QUEBEC CO.
PORTNEUF CO.
ST. MAURICE CO.
NICOLET CO.
La Tuque
Pat
Summit
Joe
Caribou
Bill
Edward
Isle
Pearl
Sanford
Stadacona
MALOUIN
Beaudet
JEANNOTTE
LINTON
DES ILES
Long
MIGUICK
LEMIEUX
Laurent
RITZ
BATISCAN
Talbot
FLOOD
Pierre
QUARRY
ROUSSEAU
HERVEY
MONTY
ST. TITE
PRICE
ST. UBALDE
PROULX
GRAND MERE
TORTUE
ST. NARCISSE
CARMEL
Shawinigan Falls
River St. Lawrence
Trois Rivieres
ch.

Reconnaissance for Primary Triangulation, Gulf of St. Lawrence

Results Obtained.—One astronomic station connected to triangulation; 1 base line site examined; 1 base line site selected and examined; 1 triangulation station site changed; 10 triangulation station sites selected; reconnaissance extended 60 miles.

The chief of the party and one assistant commenced work at Matane, P.Q., where the geodetic position of an astronomic pier previously established by the Dominion Observatory was obtained by triangulation to Matane lighthouse, the position of which was known. This work having been completed, the party proceeded via Quebec to Piashti bay on the north shore of the gulf of St. Lawrence, arriving there on May 24.

Reconnaissance work proper began at Beaver river, some fifteen miles west of Piashti bay, where there was some uncertainty as to the suitability of a previously chosen triangulation station. Due to a cold, backward spring, together with difficulties of transportation, considerable time was consumed in definitely ascertaining that the previously established station was not suitable, but after strenuous canoeing and portaging in the examination of several likely spots, a suitable point was finally found and marked.

The next work was the examination of a base line site tentatively selected near Natashkwan in 1923 between two stations of the main triangulation net about eight miles apart. The intervening country had not been sufficiently examined to insure that measuring could be carried out. A portion of the base line was found to pass over soft-bottomed swamps and small lakes, but this was the only option if serious, sharp deflections were to be avoided. To secure the greatest economy, part of the line should be measured during the late autumn under summer conditions and part during the winter.

It was noted that there is a difference of approximately twenty-three degrees in the magnetic variation at the two ends of the line only eight miles apart, doubtlessly caused by underlying deposits of magnetic sand.

From the Natashkwan base line the party proceeded to Harrington and, after considerable searching, managed to select a suitable base line site which fitted very nicely into the triangulation net previously established during the field season of 1924. Part of this 5-mile line runs across a soft-bottomed tide flat, and must also be measured in the winter.

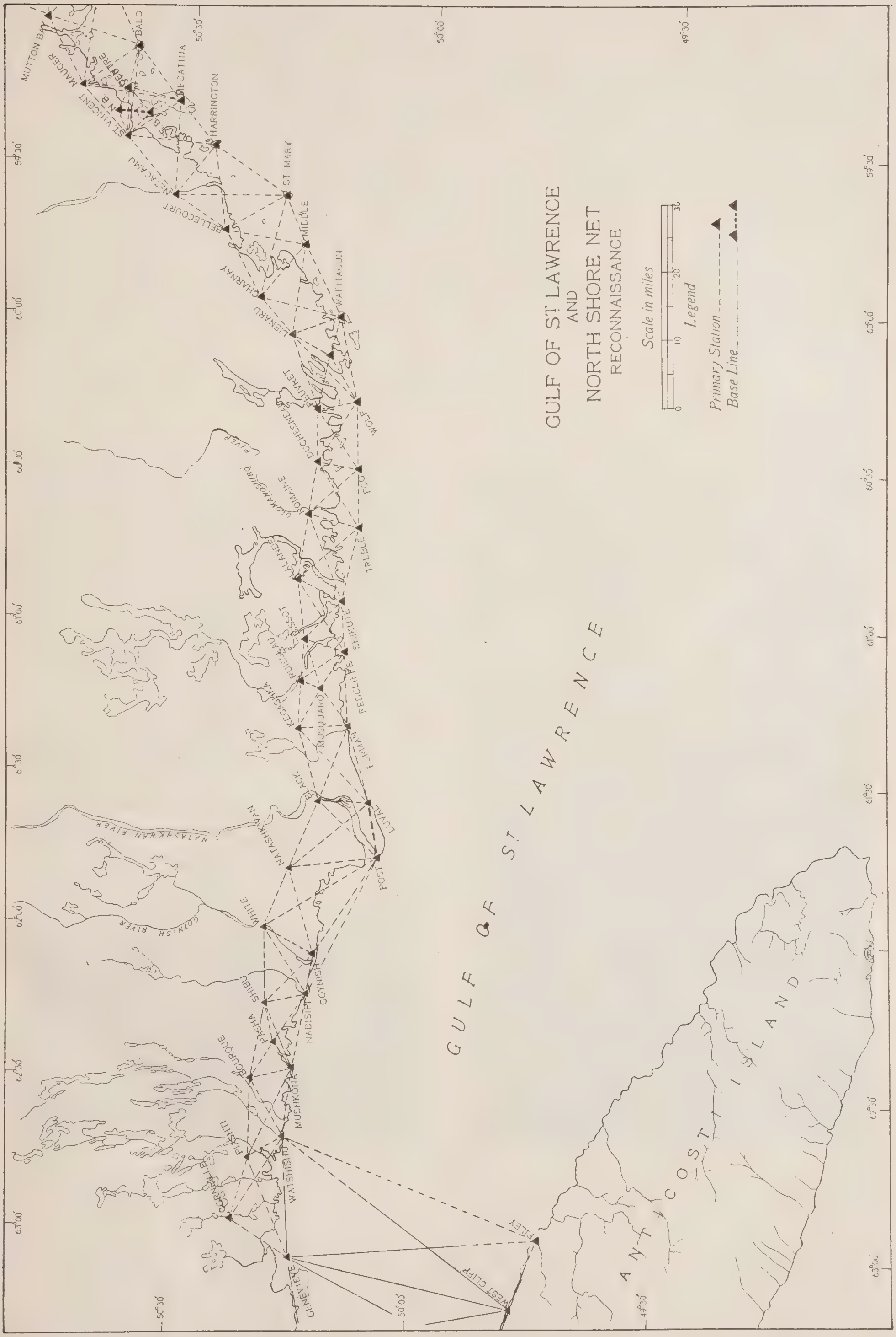
After the Harrington base line had been selected and the proper connections with the triangulation scheme established, the party again moved eastward and carried the reconnaissance from near Mutton bay almost to the mouth of St. Augustin river. By careful selection well shaped figures were secured with sides ranging from eight to fifteen miles in length. All points chosen were carefully marked and descriptions prepared.

Generally speaking, weather and working conditions were unfavourable to speedy progress throughout the season except for a short interval during the month of August. As many as five days per week of fog and rain were encountered and difficulties of transportation also hampered progress.

The country covered by reconnaissance during 1925 is rocky and barren with many muskegs. Vegetation is restricted to moss and other plants common to muskeg country, scattered clumps of brush and a few patches of small timber in the ravines near sea-level. Wood for the construction of signals had to be cut where available and carried by boat to the nearest landing place; thence it was man-packed to the site of the station.

The rough and wet nature of the country made the choosing of camp sites a difficult matter, and the absence of fuel on some of the islands off the coast necessitated the regular transportation of firewood.

A sketch of the proposed triangulation on the north shore appears on page 17.

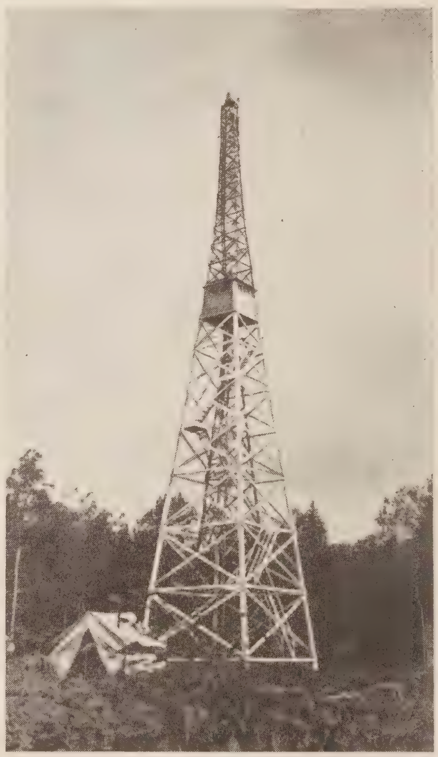

GULF OF ST LAWRENCE
AND
NORTH SHORE NET
RECONNAISSANCE
Scale in miles
Legend
Primary Station
Base Line
GULF OF ST LAWRENCE
ANTICOSTI ISLAND
MUTTON BAY
BALD
HARRINGTON
ST MARY
MIDDLE
BELLECOURT
CHARNAY
LIENARD
WOLF
TREBLE
POST
LUVAL
NATASHKWAN
WHITE
GOYNISH
HABISHI
SHIBU
PASHA
BOURQUE
MUSHKOTA
WATSHISHU
RILEY
WEST CLIFF
NATASHKWAN RIVER
GOYNISH RIVER

Primary Triangulation in Maritime Provinces

Rsults Obtained.—Reconnaissance—in Prince Edward Island, 3 stations selected; in Nova Scotia, 35 primary and 4 supplementary stations selected; distance covered in Nova Scotia, 160 miles. Station preparation—4 lamp-stands extended; 10 towers built; 12 stations monumented, distance covered, 100 miles. Angular measurements—19 primary stations completed; positions of 21 supplementary stations and lighthouses established.

The Chaleur Bay primary triangulation was commenced near Campbellton, N.B., in 1924, and was extended eastward with the ultimate aim of connecting with primary triangulation of the St. Lawrence River scheme previously completed to Percé. All but four stations of this connection were occupied in 1924 and these remaining stations were observed early in 1925. Thev presented no difficulty, except the transportation of an observing outfit into Pabos station, forty miles up the Grand Pabos river in the interior of Gaspé, over a very rough tote road. A preliminary value of the length of the Charlo base line near the head of Chaleur bay, calculated from the Anticosti base line, about 200 miles distant, agrees satisfactorily with the measured length of the former, the difference being less than two inches in a length of 4.4 miles or, expressed as a ratio, 1 in 150,000.

Tabusintac Tower, New Brunswick. Signal light tied to mast 105 feet above station mark.



Ashton Tower, New Brunswick. Height of tripod 81 feet, height of lampstand 132 feet.

The observing on the east coast of New Brunswick scheme was commenced before the end of June. Earlier investigations had shown that the lamp stands on the towers in the section between Bathurst and Chatham, N.B., would have to be elevated. The difficulties of reconnaissance in this section were largely added to by the fact that the connection with the Chaleur Bay scheme required stations to be located at Red Pine and Nipisiguit, while the southern work

finished on the line Ashton-Chatham, north of the Miramichi river some twenty miles to the south. Between these east and west lines the topography rose gradually from sea-level, on the north and south sides, to a central plateau of about 500 feet elevation and from eight to ten miles deep in a north and south direction, flat with no pronounced differences of elevation, very heavily wooded, but with slight ridges with pine trees over 100 feet in height. Thus the four exterior stations were definitely fixed in location, and the interior points had to be chosen so as to overcome the difficulties of the plateau and the high timber. These difficulties were most economically met by building the tripods of the towers of moderate height and extending the lamp-stands sufficiently high to overcome the local obstruction.

The following table shows the height of tripod and height of lamp-stand of the towers covering this section:—

	Height of tripod Feet	Height of lamp-stand Feet
Ashton	81.3	132.2
Chatham	73.9	110.4
Bartibog	69.0	105.5
Tabusintac	84.0	90.0
Red Pine	89.0	137.2

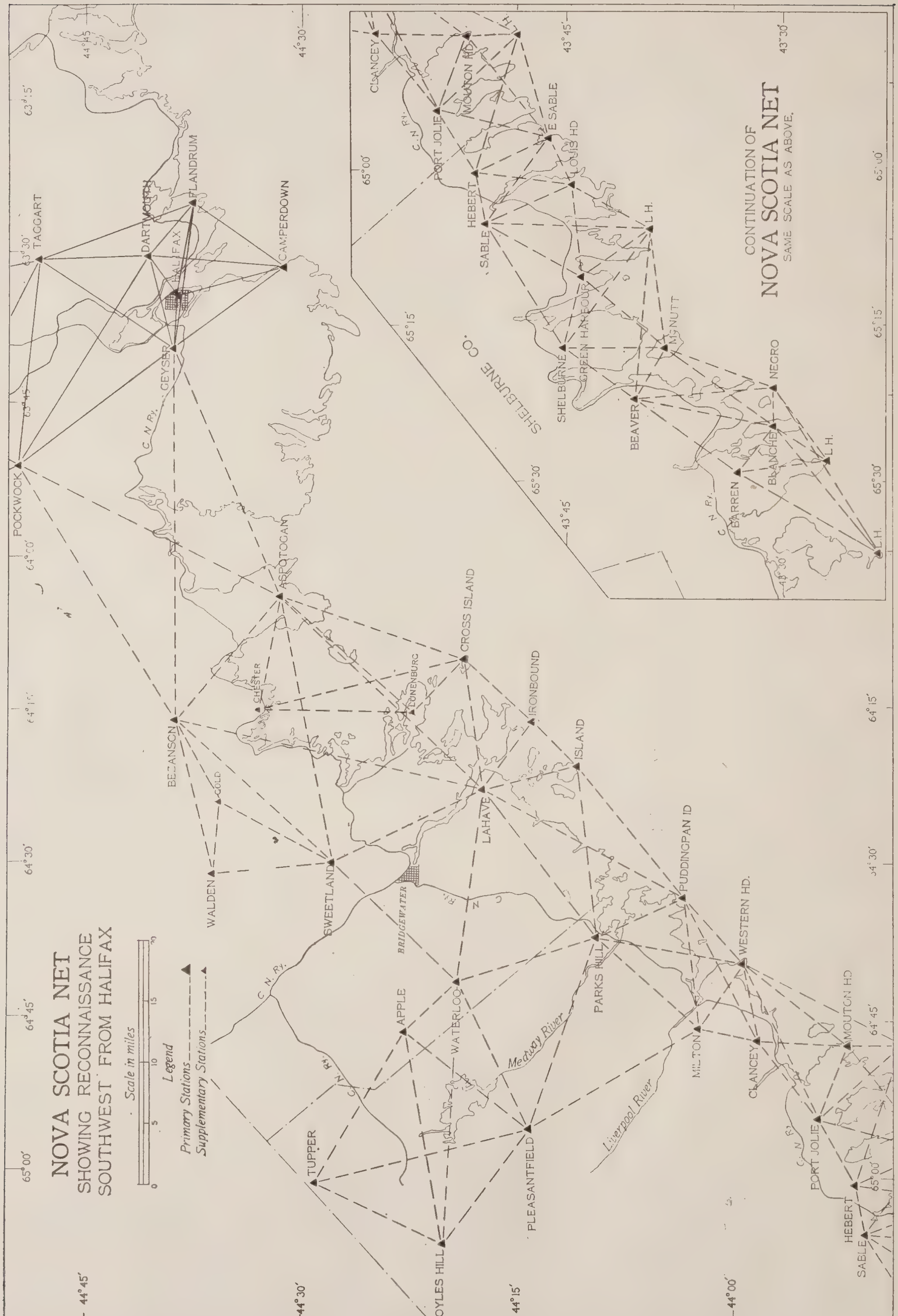
The extensions were built, piece by piece, of 2-inch by 4-inch by 16-foot spruce scantling with one foot overlap at the joints and panel bracing of 4-inch boards, guyed by one set of four wires thirty feet above the top of the original tower. A ladder was framed at one corner on the inside for ease in setting and looking after the signal lights. The structure was gradually tapered from a base of six feet square to three feet square at the top and, while appearing to be quite slender, was amply strong to bear the weight of two men, a lamp, and battery equipment. Only in severe squalls was marked vibration set up in the lower portion of the tower and this could have been materially lessened by additional guys on the extension and the tightening up of the existing guys on the lower structure. The towers at Red Pine and Ashton are being used as lookout stations for fire protection by the New Brunswick Forest Service and, at their request, the extension at Red Pine was removed late in the fall of 1925.

In the winter of 1922 the Department of Public Works measured a base line across the mouth of the Miramichi river and based a survey of the river and bay thereon. A very accurate scheme of resection based on three lighthouses intersected from the primary stations enabled the positions of the ends of this base to be determined and its length checked. To avoid much labour in the subsequent reduction, it is advisable in work of this kind to observe all the stations visible at every station and to discard the surplus lines subsequently. The method of co-ordination in this case proved most economical, requiring only one half day's observing, and transportation expenses of less than fifteen dollars.

It was desirable, from the viewpoint of accuracy in the main scheme, to obtain the line Eel to West Point across the water of Northumberland strait. Sufficient elevation at either end could not be obtained to assure the reconnaissance engineer that this line was open, but, with a value of the coefficient of refraction slightly above normal, no difficulty was experienced in getting the observations. Similar remarks also apply to the line West Point-Botsford.

At the conclusion of the season, observations had been made as far south as Indian and Egmont. Within another season, the few stations between Moncton, N.B., and the bay of Fundy series will be observed, thus completing an international circuit of triangulation of 1,800 miles.

Three stations covering the northwestern half of Prince Edward Island were selected to complete the control in this section of the country.


NOVA SCOTIA NET
SHOWING RECONNAISSANCE
SOUTHWEST FROM HALIFAX
Scale in miles
Legend
Primary Stations
Supplementary Stations
CONTINUATION OF
NOVA SCOTIA NET
SAME SCALE AS ABOVE.
TAGGART
DARTMOUTH
FLANDRUM
HALIFAX
CAMPERDOWN
GEYSER
POCKWOCK
ASPOTOGAN
CROSS ISLAND
CHESTER
LUNENBURG
IRONBOUND
ISLAND
LAHAVE
GOLD
WALDEN
SWEETLAND
BRIDGEWATER
PUDDINGPAN ID
WESTERN HD.
PARKS HILL
WATERLOO
APPLE
MILTON
CLANCEY
MOUTON HD
PORT JOLIE
HEBERT
SABLE
TUPPER
PLEASANTFIELD
BOYLES HILL
Medway River
Liverpool River
E SABLE
LOUIS HD
L.H.
SHELBURNE
GREEN HARBOUR
McNUTT
NEGRO
BEAVER
BLANCHE
BARREN
SHELBURNE CO.
C. N. Ry.

The reconnaissance for primary triangulation in southwestern Nova Scotia commenced May 1 and was continued until the last of October. The main object was the extension of a primary triangulation net from Halifax to cape Sable. The party consisted of the engineer and one assistant. Transportation throughout the season was effected by motor car.

The line Pockwock-Geizer, a side of the Halifax Extension net, was used as a base. From this line an extension was made southwest by selecting thirteen stations in Lunenburg county, eleven in Queens, and fourteen in Shelburne county. The width of the net was from five to twenty miles, the number of towers required 25, averaging 50 feet in height, and the number of ground stations 11. Queens and Shelburne counties are comparatively flat and heavily wooded, requiring the use of many high towers and short lines. In Lunenburg county, not only are the hills higher but they are less heavily wooded, and on that account triangulation is more easily and economically carried on.

During the month of August a truck and a 78-foot portable tower were used. This tower could be erected to its full height in less than three hours and dismantled in less than one hour by two men. It proved to be of great assistance in this flat country. After completing the net along the south shore, a start was made on a net from Liverpool to Annapolis, and about half the distance was covered. The season was particularly cold, rainy and foggy, which greatly retarded the progress of the work.

A sketch of this triangulation in southwestern Nova Scotia appears on page 20.

GEODETIC ASTRONOMY

Eight Laplace stations (triangulation stations at which the astronomical longitude and azimuth are observed) were established during the field season of 1925.

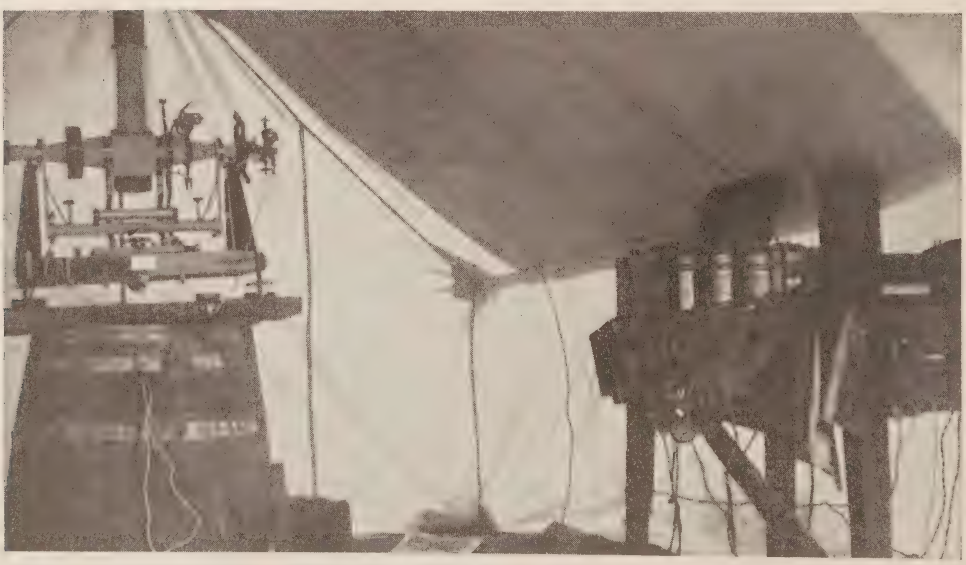
One of these stations, Cameron, was in the upper Ottawa River net; two, Jeanette and Chambord, were in the northern Quebec net south of lake St. John; five were located in the 49th Parallel triangulation net between the 109th meridian and Emerson, Man., at triangulation stations Alkabo, Estevan, Lyleton, Killarney, and Morden.

The longitudes of the first three stations were determined by the wireless method, those at the latter five by the telegraphic method, wire connections being made with the Dominion Observatory, Ottawa. In the wireless method the Annapolis 10 p.m. mean time signals were compared with the sidereal chronometer at the observing station by means of an intermediate clock which gains thirty minutes per day, the coincidence method of comparison being used.

The determination of longitude by wireless has now passed the experimental stage, and the results so obtained are as accurate as those obtained by the telegraphic method. At the three 1925 stations and also at Sheep Creek station observed in 1924, the range of determinations of longitude on the several nights rarely exceeded five or six hundredths of a second of time. There is little doubt that in nearly all future work the wireless method of longitude will be used. The expense of longitude determinations is somewhat reduced by the use of the wireless rather than the telegraphic method, as there is no rental for telegraph wire, or expense of stringing a loop from the telegraph line to the observing station. A great advantage is that Laplace stations need not be chosen near the telegraph line.

The direction method of azimuth observations was employed at all stations, and in addition to the astronomical longitude and azimuth observations required for the Laplace equation, the latitudes of the stations were also determined.

Wireless Longitude Stations. The stump of a tree cut at a convenient height serves sometimes for an instrument stand in outlying country where cement for a concrete pier is not easily obtained.



Wireless Longitude Stations. An oak pork barrel obtained at a neighbouring lumber shanty and filled with stones takes the place of a concrete pier.

A recognized feature of azimuth determinations on the prairie is the effect of refraction on lines close to the ground, in which areas it is much more prevalent than on lines from mountain top to mountain top. For this reason the determination of a primary azimuth on the prairie should depend on observations made on at least three nights with eight to twelve positions on each night.

The weather conditions were excellent at the 49th Parallel stations and all observations were completed in less than two months.

BASE LINES

Two primary base lines were measured during the 1925 season by a special base line party. One was located in the Ottawa River triangulation net and the other at the southern end of the northern Quebec net.

The Allumette base is situated on Allumette island in the Ottawa river opposite the town of Pembroke, Ont., and its measurement occupied the time from June 8 to July 7. The length determined for one base was 9092.14 metres. Elevations were provided by trigonometric levels from a precise level bench-mark at Pembroke to the base line. No particular difficulties were encountered except in locating the line so as to clear all buildings. A deflection point was unavoidable near the west end, and a right-angled offset for a 200-metre section of the line was necessary to pass a small house.

On the completion of the base the tapes were standardized at Ottawa, while the outfit was moved to the Tortue base line about fifteen miles north of Three Rivers, P.Q.

The Tortue base was located along the right of way of the Grandes Piles branch of the Canadian Pacific railway. The main part of the line was located along the edge of the ditch and deflection points near both ends were required. About a third of the length was over swampy ground, so that platforms had to be built to support observers and weight-men. The posts for supporting the tape in this section had to be braced by long poles to the solid ground of the railway embankment, and it was always necessary to exercise the greatest care while measurement was in progress to ensure rigidity of the posts.

The length of the base was 7,600.96 metres. Work on this base was completed on August 11 and the invar tapes were taken to Ottawa for standardization.

STANDARDS

As usual the three invar fifty-metre base line tapes were standardized from the standard metre-bar of the Geodetic Survey before and after measuring each base. The changes in the lengths of these tapes from time to time are not large, but are yet such as to be appreciable in primary operations. To ascertain whether or not the length of a tape has remained constant it is necessary that its length be determined from the standard bar at frequent intervals.

In addition to the base line tapes, three fifty-metre invar tapes used on the precise traverse work in British Columbia were standardized in the spring before being used, and also in the fall after the year's work was completed. It was found that they had shortened by amounts varying from 200 to 500 microns, or from 1 in 250,000 to 1 in 100,000. This was approximately what was expected from new tapes such as were used on this kind of work.

The precise level rods of the survey were all restandardized in November, 1925, and it was found that the lengths had not changed appreciably.

LEVELLING

Office Operations

During the past year the office section has chiefly been occupied with the consolidation of the levelling work taken over from the Topographical Survey, and with the assembly and co-ordination of such levelling, recorded by various organizations, as may be useful for general record. The consolidated levelling now amounts to 58,000 miles of levels, all of which is recorded in a form convenient for reference.

The most important sources of outside levelling are other federal organizations, the provincial governments, railways, and various public utility companies In order to assemble as much of such levelling as may be generally useful, correspondence has been carried on with many organizations with a view to finding out what may be available.

A great amount of information regarding elevations is available from the profiles of the various railways. Modern railway levelling is generally good, but the datum used always requires examination, and in almost every case considerable adjustment is needed to refer a profile to mean sea-level. Profiles are not a convenient form for reference, and for this reason lists of elevations are made from them. Such lists give the mileage, elevation and description of each point selected, the points including all stations, road crossings, junctions and other rail elevations easily identified on the ground, such as farm crossings, culverts, etc., so as to average three or four records per mile. The Geodetic Survey is well equipped to make the proper adjustment required for these railway levels owing to the number of the connections between its levels and the railway lines. During the year 144 rolls of railway profiles, covering 4,100 miles of railway, were received, and the elevations along about 2,700 miles have been listed and adjusted to mean sea-level. The adjustments have been found to be very complex, and an extensive knowledge of the connections between all lines of levels is very necessary.

An index is being made of the miscellaneous levelling carried on from time to time by various organizations for special purposes. This will supply a ready reference to all the levelling work done in different districts. Much of such levelling may have general value apart from the special purpose for which it was done. The plan adopted is first to make an index showing what has been done, and subsequently to collect detailed information from such of the levelling as appears to have a wider value.

Two pubications were issued during the year: No. 14, Co-ordination of Bench-Marks in Calgary, Alberta; and No. 15, Saskatchewan Bench-Marks. The former is a small pamphlet of six pages giving the correct elevation of a number of bench-marks established by various organizations, all the elevations being referred to mean sea-level, as determined by the adjustment of the Canadian precise level net made in January, 1923. The object of this pamphlet is to facilitate the use of mean sea-level as a datum for all lines of levels radiating from the city, no matter by what organization such lines may be run. The second publication contains 7,148 miles of secondary control levelling, with 2,157 bench-marks in the province of Saskatchewan. With few exceptions the levelling follows meridians, base lines or township outlines. The publication is similar to "Alberta Bench-Marks" published in 1924. The two publications have released the results along 10,950 miles of levelling, including 3,415 bench-marks.

Much work has been done in tabulating and indexing the work of past seasons. This has become necessary owing to the greatly increased number of references which must be made to the lines of levels when considering the connections with levelling done by other organizations.

A great number of elevations have been supplied in reply to inquiries, but the inquiries might usefully be more numerous in view of the amount of information which is available. This latter fact is not generally realized by many organizations whose work could be assisted by such information. It is, however, also true that there are many areas through which no lines of levels have yet been run, so that no information can be given in reply to inquiries about these areas. Such inability to supply information has a discouraging effect on future inquiries. The chief advantage of more widespread knowledge of the extent of levelling already done is that it would assist all organizations doing levelling in a certain district to connect the various lines of levels.

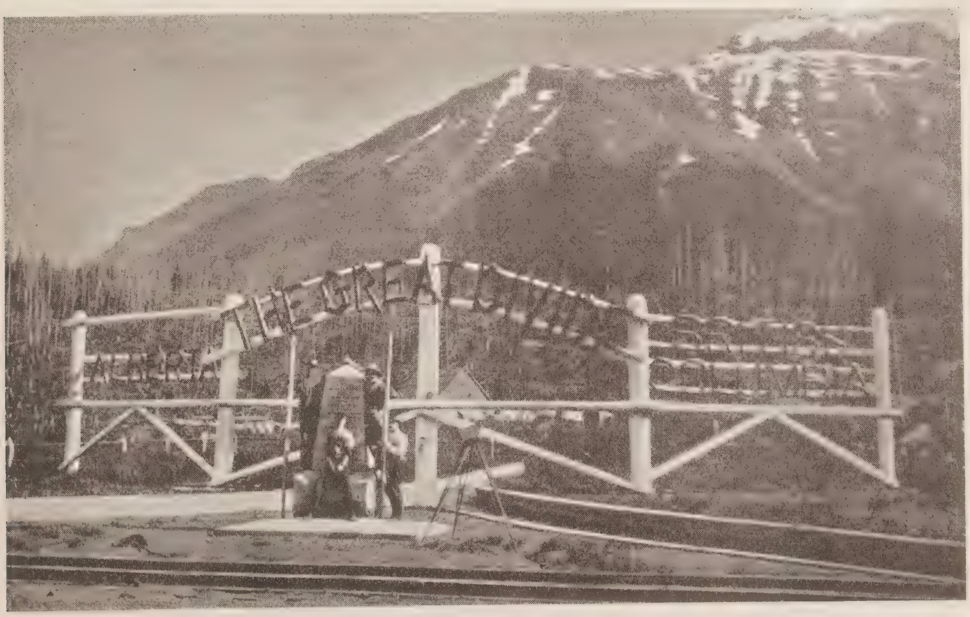
Considerable investigation regarding the proposed new edition of "Altitudes in Canada" has been made. It is now ten years since the last edition was published, and in the intervening period a large amount of new information has become available.

Regarding work of the office section in general, there is much information now on hand which might usefully be published in a number of small pamphlets, each dealing with a certain class of elevations.

Field Operations

Due to the transfer of the members of the Topographical Survey levelling division to the Geodetic Survey, field operations in precise levelling were carried out on an augmented scale during the summer of 1925. Five parties were in the field, whereas in the year 1924 there were but three.

Before describing in detail the work of the different parties it will be well to make mention of two or three changes in field procedure with regard to bench-marks which have been put into effect with the opening of the present season's operations. These changes were brought about largely as a result of the systematic inspection of old bench-marks which has been in progress for the last two years and of which mention was made in last year's report.



A monument such as the one placed on the right of way of the Canadian Pacific Railway to mark the Great Divide, is suitable for the establishment of a permanent precise level bench-mark tablet.

The most far reaching of these changes is the substitution of the bronze tablet type of bench-mark in place of the copper bolt used in the past. As stated in reports of the last two or three years tablets were used in the levelling along the Winnipeg and English rivers in northern Ontario, also in the extensive special levelling in the city of Quebec and vicinity. The table has a three-inch shank and a three-inch disc face upon which the following wording appears: "Geodetic Survey of Canada, Ottawa, B.M." The tablet is cemented into solid rock, or into structures of masonry or concrete and may be set either horizontally or vertically. The plain lettering on the face of the tablet avoids the air of mystery which pertains to a copper bolt upon whose comparatively small face only the initials of the survey can be stamped. For this and other reasons it is felt that the tablets will suffer less defacement at the hands of vandals—a practice which the inspection has disclosed to have been of all too frequent occurrence in the past. Nor has the value of the tablets, in keeping the name of this survey and its efforts in behalf of accurate levelling prominently before the engineering public been lost sight of. Having been thoroughly tried out on special work their use has now been adopted as standard practice.

Another change, in the direction of increasing the permanency of field records, is in connection with the concrete bench-mark piers constructed at intervals along all precise level lines. It has been found that several of the piers constructed in the earlier days had been broken off—in some cases doubtless by frost action and in others through vandalism. While the form of monument first designed was later improved by increasing its cross-section, a further improvement has now been effected by reinforcing the monuments with four five-foot rods of three-eighths-inch twisted steel. It is hoped that the addition of the rods will make the monuments practically indestructible.

Further development of the ideas of permanency and of educational value has resulted in the construction, at certain specified points, of a new and enlarged type of monument to be known as a "fundamental bench-mark." The intention is to build these in the cities and more important towns and junction points, and to have each such monument considered as the governing bench-mark for the town and surrounding district. The monument, wherever possible, will be constructed in a park or public square, the selection of the site being carried out in collaboration with the municipal authorities in order that, as far as can be foreseen, the location chosen be free from disturbance in the future by reason of building or grading operations or other changes. The actual monument or "fundamental bench-mark" is constructed of concrete and takes the form of a frustum of a pyramid, two feet square at the base, eighteen inches square at the top and seven feet in height, reinforced with four twisted steel rods. The excavation for the structure is carried to such a depth that only from twelve to fifteen inches of the column projects above the natural ground surface; it rests on a circular base six feet in diameter and one foot thick, reinforced by rods placed radially, the base and the column being constructed as a monolith. In the event of bed rock being encountered at a less depth than six feet the base is omitted and the column is keyed to the rock by means of the four vertical rods. A bronze tablet of standard form is set vertically in the top of the monument and the elevation determined for this is listed as the elevation of the fundamental bench-mark. In order, however, to provide for the recovery of the elevation, should the tablet or the top portion of the monument be damaged, a second tablet known as the subsurface mark, is set in the concrete base at one side of the column. This is protected by means of two sections of six-inch sewer tile, capped with metal or concrete and reaching to within about a foot of the ground surface. (See illustration on page 27.)

Precise Levelling in the Province of Quebec.—In the month of April a request was received from the Dominion Observatory for the relevelling of the precise

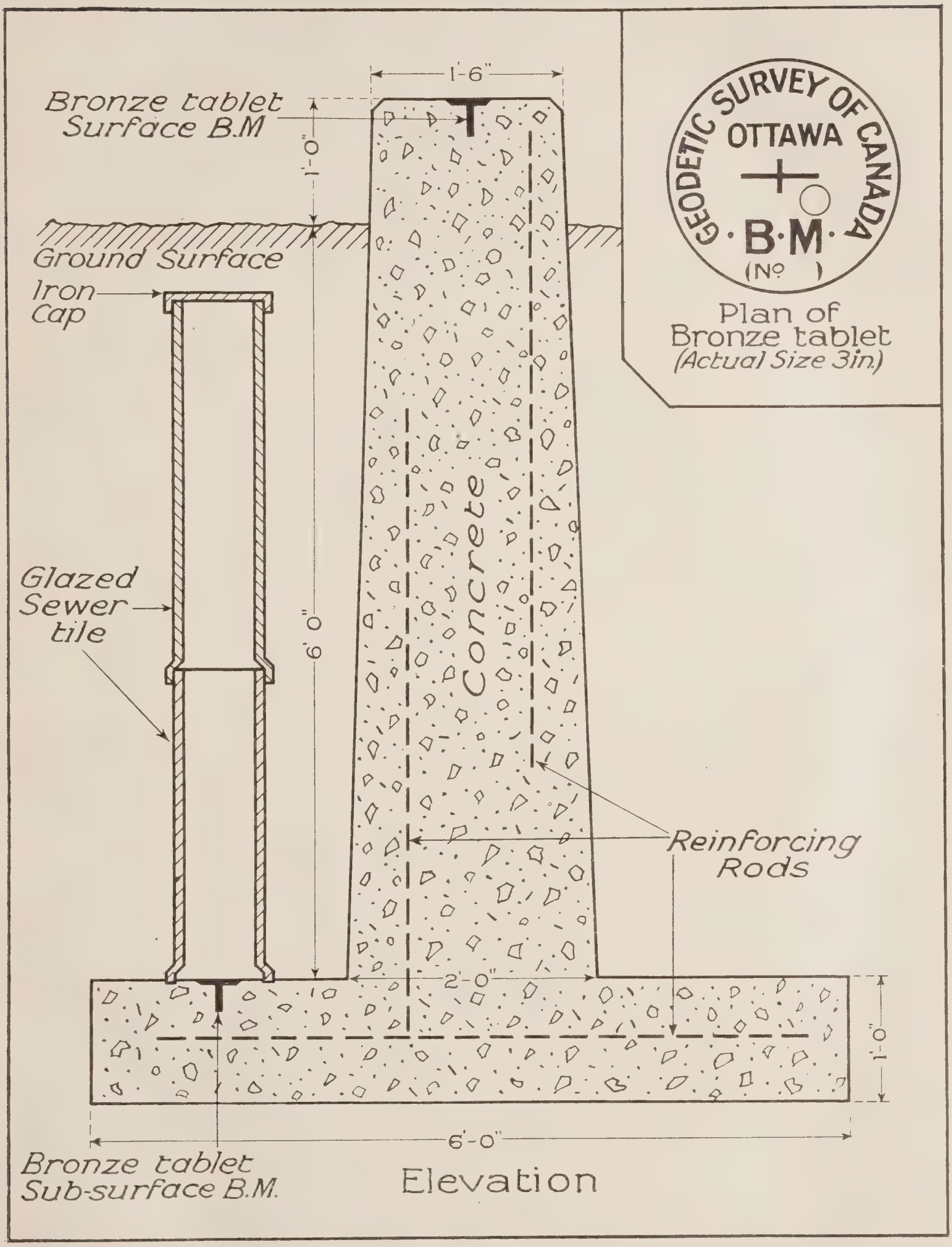


Diagram of Fundamental Bench-marks. Inset—Drawing showing all standard tablets. The conspicuous surface mark is intended for the convenience of the public and will have its elevation above sea level eventually shown on the mark itself, in addition to being published. The elevation and description of the subsurface mark will not be published as the main purpose for the establishment of this mark is to secure permanency. It is not intended for public use and when the necessity arises its recovery will be made by officers of the Geodetic Survey.

level line along the Canadian National Railway between Rivière du Loup and Levis in order to determine what vertical displacement, if any, had been caused by the earthquake of February 28, 1925, which was felt with particular severity in certain localities between these points.

To comply with this request a levelling party left Ottawa at the end of April and began work at Rivière du Loup. The line was completely relevelled between the points above mentioned, connections being made with all bench-marks established at the time of the original levelling. At the same time twenty additional bench-marks were established, thereby adding considerably to the permanence and utility of the levelling. Briefly, the relevelling indicated in general a slight lowering of the land along the westerly portion of the line, starting in the neighbourhood of St. Pacome and reaching a maximum of 0.37 foot near Montmagny. West of Montmagny the change in elevation tended to become still less.

The relevelling having been completed on the last day of June the party moved to Linton, on the Quebec-Chicoutimi line of the Canadian National railway and spent the remainder of the season, till October 29, in extending to Chicoutimi the levelling which had been carried as far north as Linton in 1919. Branches to St. Felicien, Isle Maligne and Bagotville were included; also, at the request of the Quebec Development Company, some special levelling was carried out in connection with power and other development work in the Saguenay River district. The cost of the latter work, $143, was assessed against the company. Bench-marks and gauges of the Quebec Streams Commission and of the Duke-Price Company were tied in at several points, and at Chicoutimi and Bagotville bench-marks of the Tidal and Current Survey, Department of Marine and Fisheries, were similarly connected, thereby enabling all the elevations based on these bench-marks and gauges to be reduced to the precise level datum, mean sea-level.

Precise Levelling in Eastern and Central Ontario.—The main work of this party for the season was a revision of the precise level line run in 1908 along the Canadian National (at that time Grand Trunk) railway between Prescott and Port Hope. This line, parallelling the St. Lawrence river and the north shore of lake Ontario and passing through a thickly populated and industrialized section of the province, is considered one of the most important lines of the level system and it was recognized to be of such major importance that its accuracy at all points should be beyond question and that it should be marked by an ample supply of bench-marks of the best class. The revision of the line during the present season has resulted in the fulfilment of both these requirements, the improvement of methods since 1908 and the use of levelling rods of the invar pattern having brought about better closures of the circuits of levelling lying to the north of the line. Seventy-one additional bench-marks were placed, of which number seven were fundamental bench-marks of the type described earlier in this report. These were built in the following places: Prescott, Gananoque, Kingston, Deseronto, Belleville, Trenton, and Port Hope. Of the sixty-five bench-marks established in 1908 or later, fifty-six were found to be still in existence; connections were made with these and also with the bench-marks of the Public Works Department of Canada along the Montreal-Toronto highway wherever the latter was reasonably accessible from the railway. Branch lines were run from Gananoque Junction to the town of Gananoque and from Napanee to Deseronto, these towns not having been touched by the levelling as originally carried out.

The period occupied by the above revision extended from May 14 to August 15, and on its completion a line was run along the Coboconk branch of the Canadian National railway from Port Hope to the village of Coboconk and thence along the highway to Miners Bay, on Gull lake, fourteen miles north of Coboconk. This work occupied between two and three weeks.

Precise Levelling in Alberta.—The operations of two parties were confined entirely to rerunning certain precise level lines in order to improve the closures of several circuits which for some time past have been recognized as being defective in this particular. The reduction of abnormally large closing errors is essential in order to strengthen the western portion of the precise level net and render possible an adjustment which can be held as standard without the danger of being upset by the discovery of local errors later on. While additional revision in the West is still necessary, the work accomplished this season has been very beneficial and each line run has had the effect of reducing very substantially the closures of certain circuits. A list of the lines re-run will be found in the summary later in this report.

The lines were not for the most part deficient in bench-marks; advantage was taken, however, of the opportunity to install additional ones where desirable and also to construct fundamental bench-marks at the junction points.

Precise Levelling in Southern British Columbia.—The levels along the Kettle Valley railway which had been discontinued in the fall of 1924 at Chute Lake, a short distance east of Penticton, were continued from that point in 1925 to its terminus at Midway and thence the Canadian Pacific railway was followed to Nelson and Procter. At each of these places connections were made with the gauges of the Department of Public Works on Kootenay lake. A branch line from South Slocan to Slocan, at the foot of the lake of the same name, was also included.

As in the previous season, though not to the same extent, the progress of the party was delayed considerably by the heavy grades encountered. The season's work was concluded at Procter on November 5.

Inspection of Bench-Marks.—The systematic inspection of the Survey's precise level bench-marks, the necessity for which was stressed in last year's report, was continued during the summer of 1925, trips being made by the inspector of levelling in portions of Ontario and Quebec. Including the 1923 and 1924 operations a considerable section of Eastern Canada has now been covered, embracing the provinces of Nova Scotia and New Brunswick, that portion of Quebec south of the St. Lawrence river and the majority of the lines in the province of Ontario east of Toronto.

As practically all the lines inspected had been levelled along railway tracks a railway motor car was used for purposes of transportation, an aggregate distance of 2,300 miles of track being covered in the course of the 1925 work. On the lines inspected there were originally 690 bench-marks, established between 1906 and 1919; of this number, 64, or slightly over 9 per cent, were found to have been destroyed or rendered inaccessible by alterations to bridges, buildings, etc. As in the 1924 inspection, a record was kept of the condition of the copper bolts of which the bench-marks consist and it was found that 75 per cent of the bench-marks still in existence were in as good condition as when first installed; 19 per cent were in fair condition, i.e., somewhat defaced by mischievous individuals, but the figures and letters stamped on the copper still legible or partially so; 6 per cent were completely defaced, all marking having been obliterated or in a few cases the bolt extracted from the hole. The descriptions of many bench-marks had to be revised on account of the various changes which take place from time to time; railway mile posts are in some instances moved and renumbered; reference objects such as flag-stations or passing-tracks are removed, or in other cases additional ones, which may with advantage be used as reference points, are installed; station names are occasionally changed; small bridges or open culverts are reconstructed into box culverts, often without disturbing the bench-mark therein; commercial buildings are added to and perhaps used for new purposes; private houses in which bench-marks have been installed change ownership, etc.—these are some examples of what may be encountered in the course of an average inspection trip.

It is considered to be particularly desirable that the description issued to the public from time to time should be accurate and, as far as reasonably possible, up to date; while it may still be quite possible for an engineer to find a bench-mark from a description which is not accurate and up to date, a bad impression is created and the accuracy of the instrumental and mathematical work as well may very naturally be questioned where a defective description is used as a criterion.

Aside from revising the descriptions and deleting from the records such bench-marks as have been destroyed, very valuable information is being gained as to the permanence or otherwise of different classes of bench-marks. In this connection a rather disappointing feature in some of the older lines checked over during the present season was the discovery that nine of the concrete bench-mark piers constructed to give added permanence to the bench-mark supply had been broken off or otherwise destroyed, either by reason of frost action or poor quality of concrete or through vandalism.

Summary of Field Work

Party	Mileage Levelled	Percentage Relevelled	Bench-mark Piers Built	Total Bench marks set
Quebec	351	10	24	173
Ontario	219	17	13	91
Southern Alberta	123	23	2	3
Alberta	252	11	9	20
Southern British Columbia	288	25	27	118
	1,233		75	405

Since a considerable portion of the work in Quebec and Ontario and all the work in Alberta consisted in the retracement of old lines, the total amount of new levelling added to the precise level net during the year was considerably less than shown above, being 569 miles.

The following is a detailed statement of the lines run in 1925:—

Line	On Railway	Off Railway	Total
New Levelling	*Miles*	*Miles*	*Miles*
Linton to Chicoutimi, P. Q	174·5	9·7	184·2
Saguenay Power to Isle Maligne, P. Q	15·9	2·8	18·7
Ha Ha Bay Jct. to Bagotville, P. Q., and Kenogami Lake	31·4	0·0	31·4
Gananoque Jct. to Gananoque, Ont	4·5	0·7	5·2
Napanee to Deseronto, Ont	6·3	0·8	7·1
Eldon to Miners Bay, Ont	18·1	16·1	34·2
Chute Lake to Procter, B. C	251·5	5·7	257·2
South Slocan to Slocan, B. C	31·1	0·0	31·1
Revision Levelling	533·3	35·8	569·1
Rivière du Loup to Levis, P. Q	114·8	2·3	117·1
Prescott to Port Hope, Ont	157·0	15·4	172·4
Tofield to Edmonton, Alta	42·2	2·1	44·3
Tofield to Alix, Alta	79·1	2·4	81·5
Camrose to Wetaskiwin, Alta	25·8	0·0	25·8
Millet to Edmonton, Alta	31·4	0·0	31·4
Irricana to Empress, Alta	190·5	1·2	191·7
	640·8	23·4	664·2

The absorption of the precise and secondary levelling of the Topographical Survey by this office added 4,184 miles of precise and 7,448 miles of secondary levelling, making a combined net of 22,172 miles of precise and 7,448 miles of secondary levelling at the end of the 1925 season.

Previous to 1925, 5,875 precise level bench-marks had been established by the Geodetic Survey and 1,163 by the Topographic Survey; the addition of 405 during the 1925 season, as noted above, makes a grand total of 7,443 precise level bench-marks established.

The mileage of precise levelling in each of the provinces is as follows:—

Province	Mileage
Ontario	5,514
Saskatchewan	3,919
Alberta	2,866
British Columbia	2,740
Quebec	2,593
Manitoba	2,162
New Brunswick	1,096
Nova Scotia	729
Yukon Territory	458
*Minnesota, U.S.A.	89
*Vermont, U.S.A.	6
Total	22,172

*These lines were necessary to tie in on United States data.

Railway	Mileage
Canadian National	11,083
Canadian Pacific	7,220
Kettle Valley	364
Timiskaming and Northern Ontario	320
Alberta and Great Waterways	282
Great Northern	230
Algoma Central	219
Edmonton, Dunvegan and British Columbia	170
Dominion Atlantic	146
Quebec Central	109
White Pass and Yukon	91
Temiscouata	82
New York Central	55
Pere Marquette	55
Boston and Maine	40
Maine Central	36
Roberval-Saguenay	31
Napierville Junction	28
British Columbia Electric	28
Quebec Railway, Light and Power Co.	25
Alma and Jonquiere	16
Maritime Coal, Railway and Power Company	12
Pacific Great Eastern	9
Michigan Central	3
Highways and cross-country levels	1,518
Total	22,172

MATHEMATICAL RESEARCH AND ADJUSTMENTS

In this division, work has been continued from the previous year. A treatise on Higher Geodesy has been completed and prepared for publication, and is now in the hands of the printer. The adjustments of triangulation nets and of the precise level net have been caried on to include the previous season's field work as far as possible. The preliminary work of the precise traverse line in British Columbia has been done and will be ready for adjustment when the traverse is joined up with the interior triangulation. In the statistics section, a great deal of information has been given out to federal and provincial departments and to engineers throughout the country.

Adjustment of Triangulation Nets

Ottawa River.—A preliminary adjustment of this net had been made as far as the Allumette base line, near Pembroke, Ont., during the previous year, but this adjustment did not include the length control from this base nor the azimuth control from the Pembroke Laplace point. During the year these conditions were added and the adjustment completed from the line Alleyn-Masham to the base line, thus giving final values to the geodetic positions of the primary stations of the net. The changes in the values of the positions due to the introduction of the base and azimuth equations were very small.

As the next Laplace point is at Cameron, six figures farther west, and the next base line is at the head of lake Temiskaming, no further adjustment has been made for the present, as the next adjustment will include this base and Laplace point with one new Laplace point in the vicinity of the Temiskaming base.

Western Ontario.—During the past season the adjustments of three parallel nets, two primary and one secondary, in the Western Ontario peninsula, were completed.

One net, commencing at Maryboro, a station about 70 miles west of the city of Toronto, runs north for about 80 miles to Christian island in Georgian bay. This adjustment is based on five lines previously determined in the solution of the large western Ontario triangulation net and consists of thirty-three conditions: twenty-one angle and twelve side equations.

A smaller net, immediately south of the above, was also adjusted. This net is based on three fixed lines and extends from Maryboro south to Biddulph, a distance of about fifty miles. These nets form part of the western Ontario triangulation, but were not included in the main adjustment on account of the great number of conditions already involved in that net.

In order to extend the control to lake Huron, a small system of secondary triangulation was adjusted. This net is based on the primary stations Hullet and Morris, and terminates at Carlow, a station close to Goderich on lake Huron. The positions of a great number of secondary points, such as lighthouses, church spires, watertanks, etc., have been determined and are of great value to engineers in general.

Alberta-British Columbia Boundary.—The adjustment and evaluation of geographic position of the secondary triangulation along the Alberta-British Columbia boundary from Yellowhead pass northwest to Sheep Creek pass was completed during the year. The triangulation is based on the astronomical determination of the position of West Base (near Lucerne, B.C.). Field data which were used in the adjustment to increase the accuracy of this work consisted of two measured bases, one on Yellowhead lake and the other in Sheep Creek pass, and Laplace observations at East Base in Sheep Creek pass. This isolated datum will be used until the triangulation is connected with the primary triangulation of Canada and placed on the North American Datum, when the geographical positions will be subject to revision.

The net is approximately 100 miles in length and consists of thirty-four triangulation stations, and its adjustment embraces ninety-eight conditions. Geographic positions of a number of prominent mountains in the country covered by the main scheme of triangulation were determined.

The following table gives the position of a triangulation point at the north end of this net as calculated from three widely separated astronomical stations. The differences give some idea of the errors in position which may result from the acceptance of astronomically determined positions.

GEOGRAPHIC POSITIONS OF WEST BASE (SHEEP CREEK)

Calculated From	Latitude	Difference in feet from Lucerne value	Longitude	Difference in feet from Lucerne value	Azimuth West Base to East Base
Lucerne Astronomical station through 100 miles of triangulation................	53°50′06″·77		120°00′09″·45		98°12′24″·88
Sheep Creek Astronomical station through one line of triangulation............	53°50′05″·57	120	120°00′00″·27	551	98°12′32″·18
Pouce Coupe, Astronomical station through 130 miles of Boundary Survey......	53°50′07″·23	46	119°59′59″·67	587	

Eastern Quebec and New Brunswick.—In this section of triangulation, starting with stations Gaspé and Jupiter, at the mouth of the St. Lawrence river, the values were run through a chain of triangles along Chaleur bay and the east coast of New Brunswick as far as the observations of the primary stations had been completed in the vicinity of Moncton. From these values a length was obtained for a base line measured by the Public Works Department across the mouth of Miramichi river, which checked satisfactorily with the measured length to within 1 in 70,000. Preliminary values for the positions of all the points along Chaleur bay were determined to meet the requests of the province of Quebec and of the Geological Survey.

When the observing has been done in 1926 south of Moncton to connect up with the bay of Fundy points, the full circuit of 1,800 miles of international triangulation will be completed. By means of some secondary triangulation in this gap, an estimate of the closure was obtained which indicated a discrepancy of only 1 in 240,000 or roughly 1 foot to 46 miles.

Northern Quebec.—The portion of this net of primary triangulation extending northerly along the Canadian National railway to the vicinity of Linton, P.Q., from primary stations Carmel and Dusable of the St. Lawrence River triangulation, was partially adjusted to obtain preliminary values of the geodetic positions of the stations included in this district. Before a final adjustment can be made, additional field work is required at the northerly extremity of the net. In the meantime these preliminary values will be available to those seeking geodetic information in this area.

Forty-ninth Parallel.—An adjustment was made of that part of the triangulation along the 49th parallel of latitude from the United States Coast and Geodetic Survey stations, States and Canada, on the 98th meridian to the Killarney Base. The purpose of the adjustment was to test the accuracy of the field work; final values will not be available until after readjustment by the United States Coast and Geodetic Survey gives final values to these points. A length equation was also run from Ambrose Base to Killarney Base.

Triangulation of Allied Surveys.—Three secondary triangulation nets of the Geological Survey have been adjusted and evaluation of geographic positions is now nearing completion. A different mode of operation is used in each net depending on how the connection is made to primary stations of the Geodetic Survey.

The triangulation in Thetford, P.Q., is based directly on the primary line Thetford-Ham. That at lake Simcoe, Ont., has its own measured base and is connected at each extremity to primary stations Oro and Mariposa.

A tertiary triangulation net of the Hydrographic Survey based on Geodetic Survey stations at both extremities, and extending from Halifax to the strait of Canso, is being adjusted. This will give the positions of all lighthouses along this part of the Nova Scotia coast.

Precise Traverse.—Preliminary values of the positions of points on the 120 miles of precise traverse in British Columbia were worked out. These values are based on positions of primary triangulation points on the British Columbia coast in the vicinity of Prince Rupert, and will not be finally adjusted until the traverse is tied in to primary triangulation points in the interior of the province.

The accuracy of the terminal point was tested by calculating latitudes and departures at each point on the plane, summing them and reducing to the spheroid by a special conversion formula.

Adjustment of the Precise Level Net of Canada

The adjustment of the precise level net was continued to include all the work done during the field season of 1924. As stated in the report of 1925, the datum on which the adjustments are based is mean sea level at tidal stations on the Atlantic and Pacific coasts. The new work of 1924 introduced into the adjustments during the past year comprised two circuits—Cochrane-Three Rivers - Ottawa - North Bay - Cochrane, and Hervey Junction - Quebec - Three Rivers-Hervey Junction. There was also further relevelling in eastern Ontario requiring corrections to the earlier as well as the later adjustments.

The United States eastern border circuits were included as before, but two adjustments were carried on so as to give adjusted values with or without the effect of the United States levelling. In all cases the differential method was used, as it affords an easy means of adding new work as well as giving the effects of each addition. The field work of 1925 is now ready for inclusion in the adjustment. A part of this work consisted of relevelling for the purpose of reducing abnormally high closures of circuits, so as to have the whole Canadian net of uniformly high quality.

The probable error of a line of precise levelling one mile in length is ± 0.011 feet. This was obtained from the last adjustment which incorporates all precise level lines run in Canada by the Geodetic and Topographic Surveys up to the end of the season 1925.

Geodetic Statistics

A considerable amount of geodetic data has been turned in for record during the year. The preliminary work in connection with the net comprising the region between Gaspé and Northumberland strait and including Chaleur bay has furnished this area with a great many control points including twenty-nine primary stations, nineteen lighthouses and seventeen other secondary points. Records have been augmented, too, by the final positions of a number of primary and secondary stations along the Ottawa river. The final adjustment of the Geological Survey net near Madoc, Ont., has been added, which accounts for thirty-one new control points in this area. The past year has seen the completion of the Yellowhead Pass adjustment which adds forty or fifty stations to the records of this office. Another addition is the preliminary adjustment of two small nets—one in the vicinity of Grand'Mere, P.Q., and the other along the lower St. Lawrence river. In connection with the precise traverse along the Canadian National railway in British Columbia the preliminary work has given the positions of forty traverse stations.

A complete revision of the positions of the lighthouses and other secondary stations along the British Columbia coast has been made in order that final values may be given to these points. In addition, a number of adjustments for

results required by the public have been made, and positions of a considerable number of secondary stations situated in different parts of the country have been calculated.

The results obtained in the field in connection with the different triangulation systems have been turned in and have been catalogued in the usual manner. This section has supplied a great deal of geodetic information to many branches of the Dominion Government, to some of the provincial surveys, and to a number of private engineering organizations.

DISTRIBUTION OF PARTIES OF THE GEODETIC SURVEY OF CANADA DURING THE FISCAL YEAR ENDING MARCH 31, 1926

TRIANGULATION

Locality of Work	Operation	Persons Conducting Operations
Northern British Columbia	Precise traverse—reconnaissance, angular measurements, linear measurements and field calculations.	G. H. McCallum, District Engineer; C. H. Ney, G. F. Dalton, T. H. Parker.
Alberta and Manitoba......	Triangulation—reconnaissance, direction measurements, station preparation and tower building.	W. M. Dennis, District Engineer; W. N. McGrath, N. H. Smith, H. A. Blair.
Ottawa River, Ontario and Quebec..................	Triangulation—reconnaissance, direction measurements, station preparation and tower building.	A. M. Grant, District Engineer; J. H. Kihl, J. M. Riddell, W. Murphy.
Northern Quebec..........	Triangulation—reconnaissance, direction measurements, station preparation and tower building.	J. W. Menzies in Charge; E. M. Medlen, C. K. McElroy.
Gulf of St. Lawrence.......	Reconnaissance.	W. C. Murdie.
Maritime Provinces........	Triangulation—reconnaissance, direction measurements and tower building.	J. E. R. Ross, District Engineer; H. P. Moulton, L. N. Wadlin, C. H. Brabazon, N. E. Kelly.
London, Ontario...........	....	D. H. Nelles, District Engineer; F. P. Steers, B. J. Woodruff.

GEODETIC ASTRONOMY AND BASE LINES

Locality of Work	Operation	Persons Conducting Operations
....	Supervision of Field Work.......	F. A. McDiarmid
49th Parallel....................	Laplace stations.................	F. A. McDiarmid
Ottawa River and Northern Quebec............................	Laplace stations.................	T. C. Dennis
Northern Quebec.................	Base line measurement...........	K. H. Robb

LEVELLING

Locality of Work	Operation	Persons Conducting Operations
....	Supervision of field work........	F. B. Reid
British Columbia................	Precise levelling.................	G. S. Raley
Alberta.........................	Precise levelling.................	E. W. Berry
Alberta.........................	Precise levelling.................	L. O. R. Dozois
Ontario.........................	Precise levelling.................	D. McMillan
Quebec..........................	Precise levelling.................	G. E. B. Sinclair

LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia.
Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.
Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.
Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.
Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.
Publication No. 6—(Withdrawn from publication, as levelling contained is republished in Bulletins).
Publication No. 7—Geodetic Position Evaluation.
Publication No. 8—Field instructions for Precise Levelling.
Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning.
Publication No. 10—Instructions for Building Triangulation Towers.
Publication No. 11—Geodesy. In press.
Publication No. 12—Mathematical Statistics of the Geodetic Survey of London, Ont. (Distributed by the City Engineer, London, Ont.)
Publication No. 13—Errors of Astronomical Positions Due to Deflection of the Plumb line.
Publication No. 14—Levelling. Co-ordination of Elevations of Bench Marks in the City of Calgary, Alberta.
Publication No. 15—Levelling. Bench Marks Established along Meridians, Base Lines and Township Outlines in Saskatchewan.
Instructions to Lightkeepers; Use of Electric Signal Lamps being Appendix No. 4 to Publication No. 5.
The Geodetic Survey of Canada; Operations, April 1, 1912, to March 31, 1922—Publications of the International Geodetic and Geophysical Union, 1922.
Reports of the Section of Geodesy; The International Geodetic and Geophysical Union. Second General Conference, Madrid, 1924; Operations: April 1, 1922, to March 31, 1924.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1922.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1923.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1924.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1925.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1926.

Precise Levelling Bulletins

Bulletin A—
Vancouver, B.C. and adjacent district—as far east as Mission, Matsqui and Huntingdon.
Bulletin B—
Abbotsford to Resplendent, B.C.
Spence Bridge to Brodie, B.C.
Mission to Hope, B.C.
Bulletin C—
Saskatoon, Sask., to Prince George, B.C.
Prince Rupert to Prince George, B.C.
Bulletin D—
Calgary, Alta., to Kamloops, B.C.
Revelstoke to Arrowhead, B.C.
Sicamous to Okanagan Landing, B.C.
Bulletin E—
Kipp, Alta, to Golden, B.C.
Bull River to Kootenay Landing, B.C.

Bulletin F—
- Calgary to Lethbridge, Alta.
- Calgary to Tofield, Alta.
- Camrose to Wetaskiwin, Alta.

Bulletin G—
- Moose Jaw, Sask., to Coutts, Alta.
- Swift Current, Sask., to International Boundary.

Bulletin H—
- Irricana to Medicine Hat, Alta.
- Bassano, Alta., to Swift Current, Sask.
- Empress to Compeer, Alta.
- Kerrobert to Unity, Sask.

Bulletin I—
- Stephen, Minn., to Regina, Sask.
- Regina to Prince Albert, Sask.

Bulletin J—
- Napinka to Neepawa, Man.
- Minnedosa, Man., to Regina, Sask.
- Yorkton to Saskatoon, Sask.
- Colonsay to Prince Albert, Sask.
- Lanigan, Sask., to Brandon, Man.

Bulletin K—
- Emerson, Man., to Port Arthur, Ont.
- Sprague to Neepawa, Man.
- Portage-la-Prairie to Plum Coulée, Man.

Bulletin L—
- Winnipeg, Man., to Kenora, Ont.
- Winnipeg to Victoria Beach, Man.

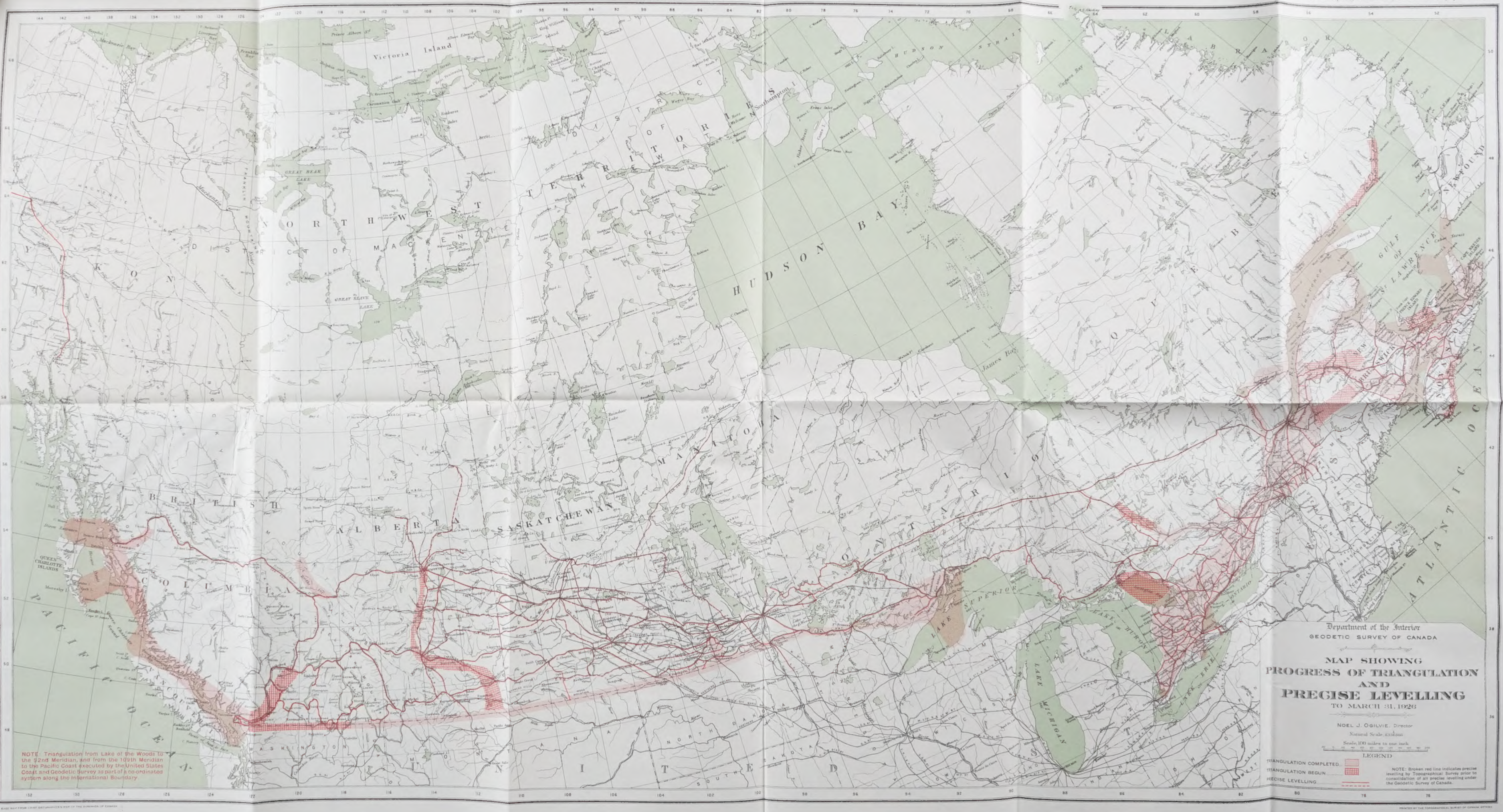
Bulletin M—
- Rennie, Man., to Armstrong, Ont.
- Superior Junction to Rowan, Ont.

Bulletin N—
- Sudbury to Cochrane, Ont.
- Armstrong to Cochrane, Ont.

Index Bulletin, Precise Levelling.
- Precise Level Lines of the Geodetic Survey of Canada in the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba, and in the northern Portion of the province of Ontario, north and west of North Bay.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Ottawa.

CONTENTS


Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
AND
PRECISE LEVELLING
TO MARCH 31, 1926
NOEL J. OGILVIE, Director
Scale, 100 miles to one inch
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
PRECISE LEVELLING
NOTE: Broken red line indicates precise levelling by Topographical Survey prior to consolidation of all precise levelling under the Geodetic Survey of Canada.
NOTE: Triangulation from Lake of the Woods to the 92nd Meridian, and from the 109th Meridian to the Pacific Coast executed by the United States Coast and Geodetic Survey as part of a co-ordinated system along the International Boundary
HUDSON BAY
NORTH WEST TERRITORIES
DISTRICT OF MACKENZIE
YUKON
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEW BRUNSWICK
NOVA SCOTIA
NEWFOUNDLAND
LABRADOR
GULF OF ST. LAWRENCE
ATLANTIC OCEAN
PACIFIC OCEAN
Victoria Island
GREAT BEAR LAKE
GREAT SLAVE LAKE
James Bay
LAKE SUPERIOR
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
QUEEN CHARLOTTE ISLANDS
Southampton I.
HUDSON STRAIT
Ungava Bay